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The new king of affordable gaming graphics **PG. 76**

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Game streaming gets a boost; will it succeed? **PG. 34**

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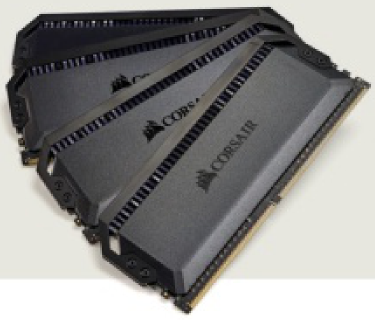

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Contributing Writers: Alex Campbell, Christian Cawley, Alex Cox, Nate Drake, Ian Evenden, Matt Hanson, Phil Iwaniuk, John Knight, Jeremy Laird, Chris Lloyd, Zak Storey
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Editor Emeritus: Andrew Sanchez

ART
Art Editor: Fraser McDermott
Image Manipulation: Gary Stuckey
Photography: Neil Godwin, Olly Curtis, Phil Barker
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BUSINESS
US Marketing & Strategic Partnerships: Stacy Gaines, stacy.gaines@futurenet.com
US Chief Revenue Officer: Luke Edson, luke.edson@futurenet.com
East Coast Account Director: Brandie Rushing, brandie.rushing@futurenet.com
East Coast Account Director: Michael Plump, michael.plump@futurenet.com
East Coast Account Director: Victoria Sanders, victoria.sanders@futurenet.com
East Coast Account Director: Melissa Planty, melissa.planty@futurenet.com
East Coast Account Director: Elizabeth Fleischman, elizabeth.fleischman@futurenet.com
West Coast Account Director: Austin Park, austin.park@futurenet.com
West Coast Account Director: Jack McAuliffe, jack.mcauliffe@futurenet.com
Director, Client Services: Tracy Lam, tracy.lam@futurenet.com

PRODUCTION
Head of Production: Mark Constance
Production Manager: Vivienne Calvert
Project Manager: Clare Scott
Production Assistant: Emily Wood

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Alan
Dexter

NEW GEAR IS COMING THICK AND FAST; PICK YOUR PARTS CAREFULLY

THE GRAPHICS CARD MARKET continues to be an odd beast: In the last few months, we've gone from having no affordable new cards to play with, to having almost too many options. And there are more on the way, meaning that the crowded landscape is going to get even more confusing.

Knowing what hardware to focus on is where we come in, and whether you're upgrading an existing machine or building one from scratch, you can rely on us to tell you what really matters. When it comes to affordable graphics cards, there are a few options for anyone not interested in the first generation of RTX cards: from last-gen AMD and Nvidia cards, to the new GeForce GTX 1660 and 1660 Ti. You'll find a review of the 1660 on page 76, while we show you how to build a whole system around the 1660 Ti on page 70.

The beauty of any build is that you can tweak it to suit you. For instance, you could use the cheaper non-Ti card in this month's cover build if you're trying to save cash, but you'll probably have to dial back from the highest settings to hit smooth frame rates—something you shouldn't have to do with the factory overclocked 1660 Ti we've used.

The rest of the build is simple enough, and a good guide for anyone looking to build a machine for the first time. You'll end up with a system that can game brilliantly, but also turn its hand to more serious endeavors without breaking into a sweat. It's a powerful machine that puts in a good turn in the value-for-money stakes.

If you're a fan of older hardware, you should find the feature starting on page 24 interesting, as it shows you how to recreate some of the machines of your youth using emulation. The likes of the Commodore 64, Atari ST, and consoles from the '90s can now strut their stuff for your entertainment, and it's far easier to do now than it was.

One thing that older systems did very well was making the most of the storage they had available, and when you look at the size of Windows 10 with this in mind, Microsoft's latest OS can appear bloated. The good news is that there are tools that can help you cut a lot of this bloat, and focus on the core functionality of Windows without a lot of the extras that you never use. On page 44, we show you how to use these tools to strip out apps you don't need to create a trimmed, stripped-down install.

Our other big feature this issue looks at the viability of Google's game streaming service, Stadia. It isn't the first such service, and it probably won't be the last, but what hurdles will it have to overcome to stand a chance, is it something that people actually want, and will having Google's sizable funds behind it mean that it can succeed where so many others have failed? Turn to page 34 to find out.

Enjoy the issue!

Alan Dexter is Maximum PC's *executive editor and a punisher of hardware. He's been a tech journalist for over 20 years, and has no problem upsetting the PC industry as a whole.*

↘ submit your questions to: comments@maximumpc.com

THE NEWS

Intel's Enterprise Division's Big Day

Server chips, Optane DIMMs, and a lot of talk of chiplets

MANUFACTURERS LOVE events, and last month it was the turn of Intel's Enterprise team to get out of the office at the Data-Centric Innovation Day, and show off what's new for big data, which also tends to highlight where tech is going.

The big launch was Intel's second generation of Scalable Xeon chips, Cascade Lake. A 48-core design was expected, but we got up to 56 cores. They are still based on Skylake, but get improved core counts, clock speeds, and memory support. These are the chips to run those cloud and big data services. AMD's rival, Rome, is due later this year, with up to 64 Zen 2 cores, providing some healthy competition.

Optane DC Persistent memory also got its proper launch, now supported by the Cascade chips. The first modules were actually shipped to Google last year, but there has been nothing to plug them into until now. This isn't the storage Optane we have on desktops; it's non-volatile memory on a DIMM. It's a little slower than conventional RAM, with latencies of around 180–340ns, compared to around 70ns, although this looks good against an Optane SSD with its five-figure number.

Optane DIMMs have a higher capacity per slot than normal RAM DIMMs, currently peaking at 512GB. You still need to fit one conventional RAM module, which acts as a buffer for the Optane DIMMs. The upshot is that you can change three 128GB DIMMs for 768GB of mixed memory—twice as much. You can run this in two modes, either using all of it as a single block of main memory, with the RAM module acting as a cache, or use the Optane DC PM modules separately as very fast non-volatile storage. The unified memory/storage paradigm is a step closer....

A while ago, Intel bought Altera, for its interconnect technology, specifically FPGA, Field-Programmable Gate Array. It's taken some time to integrate, but we now have the first fruits: chiplets. Intel has the first FPGA chips made entirely under its own name. These 10nm chips can have custom third-party chiplet extensions fitted, and will see use as DSPs, machine-learning accelerators, and other such jobs.

Intel is also developing a hybrid processor using Lakefield chiplets, which uses its chip stacking technology, Foveros, to pull various components into one SoC. The layered design has a base layer with the cache and I/O; above this sits a layer containing a Sunny Cove processor chiplet, along with smaller Atom processing cores, and the GPUs. Above this are two layers of memory. Being small enough for tiny devices, it has been demonstrated fitted into something the size of a streaming stick, yet powerful enough to drive a laptop. We should see this some time this year, if all goes well.

It has not been a completely quiet month for Intel's desktop processors either—the Core i9-9990XE is finally available, sort of. This is Intel's highest-ever numbered CPU, a Skylake-X chip with 14 cores running at a base clock of 4GHz, a two-core boost of 5.1GHz, and an all-core boost of 5.0GHz. It also has a not inconsiderable TDP of 255W. It is essentially a carefully chosen factory overclocked i9-9940X with no warranty.

Don't start planning a rig around this beast though—the i9-9990XE isn't easy to get. It was planned to be only available to system builders by a sealed auction every three months. The first of these has been held, and Pudget Systems in Washington admitted to buying one for $2,300. The company decided that the lack of warranty, unpredictable availability, and massive heat made it unsuitable. German PC specialist CaseKing has offered a system built around it for $14,671. It has also offered the chip on its own, at $3,384. Thanks, but no thanks.

Meanwhile, Intel must be wondering exactly what is in store at Computex this year, where AMD is expected to launch the Zen 2 processors, and possibly Navi as well. **–CL**

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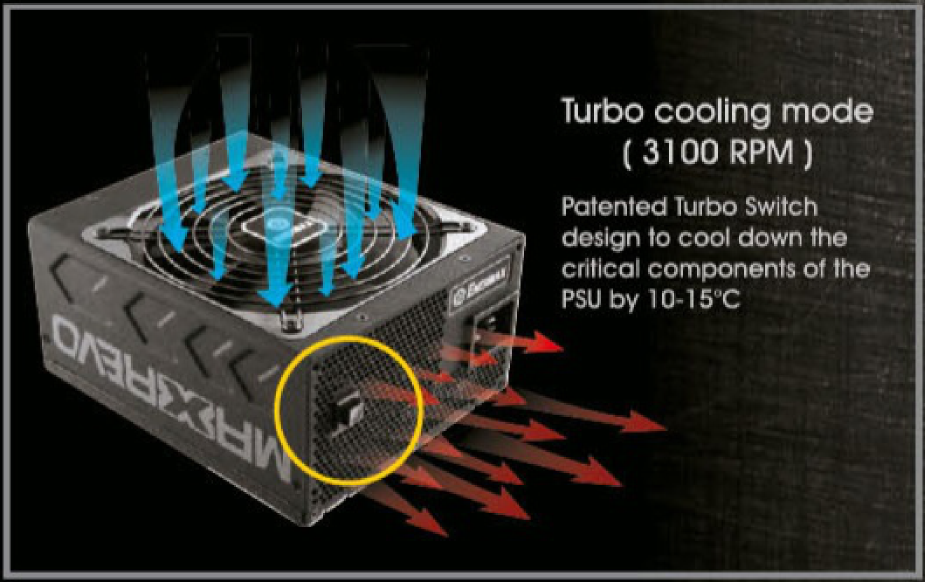
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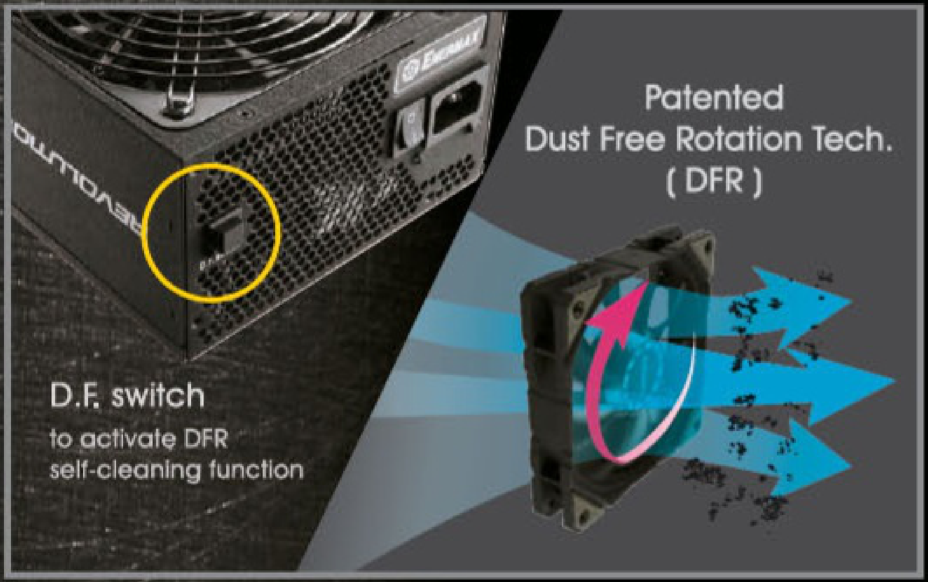
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APPLE AND QUALCOMM BURY HATCHET

Intel drops 5G modems, and peace reigns

APPLE AND QUALCOMM were at each other's throats mere weeks ago, embroiled in a huge legal battle over royalty payments. Apple challenged Qualcomm's right to charge what it did, and Qualcomm wanted Apple to pay a proportion of its iPhone revenue it owed, which it claimed had reached over $7 billion.

At the start of April, pundits still claimed the chance of any deal was minimal, and it looked set to follow the pattern of Apple's seven-year legal war with Samsung over smartphone patents. The case even got as far as the opening statements. Then, in a move that almost nobody saw coming, the two firms signed an agreement to drop all outstanding legal actions. Apple is to pay Qualcomm an undisclosed sum (rumored to be around $6 billion), and sign a six-year licensing deal with the company, with an optional extension.

Meanwhile, Intel has announced that it's leaving the 5G smartphone modem business, and has shelved plans to release 5G modems, which were due next year. This follows years of effort by Intel to get into the mobile market, and not quite getting it right. It has spent an estimated $10 billion on research and development on mobile devices over the years, and was losing a billion a quarter in 2014, the last time it reported the mobile division's business separately. It now has very little to show for it. Intel will continue to work on 5G infrastructure, but will leave the chips in phones to others.

This, then, is probably behind much of the sudden clarity between Apple and Qualcomm. If Intel can't deliver a 5G modem chip, it's not a good idea to be involved in a protracted—and expensive—legal battle with a major supplier, or customer. This leaves Qualcomm looking rather good, and its stock price showed it, jumping 20 percent at the news. Meanwhile, Apple has quietly started hiring cellular modem architects. **–CL**

FACEBOOK HAS YOUR CONTACT LIST, POSSIBLY

IT "ACCIDENTALLY" DOWNLOADS 1.5 MILLION

FACEBOOK IS HAVING a hard time keeping out of the news for its data infringements. This time, it has been harvesting people's email contact lists without permission, since May 2016. Until recently, it had been asking some new users to enter their email account passwords in order to verify their account. Facebook says this was when people signed in on systems that didn't support the OAuth security protocol. It now seems this action prompted Facebook to download your email contact list to its servers, and use it to construct a map of your social circle. Facebook claims all this was "unintentional," and it had removed the previous voluntary system prompts, but failed to remove the process.

A recent poll of security professionals put trust in Facebook at about a quarter. Making money out of your data is the core of Facebook's business, and the company is looking increasingly out of touch with its users—not good for a social network. **–CL**

SAMSUNG'S FOLDING PHONES FAIL

Screens break in days

SAMSUNG'S NEW Galaxy Fold has a problem. The first batch, sent to reviewers, have seen screens fail at an alarming rate. Reviewers can be ham-fisted, and some had removed a polymer layer from the screen that you aren't supposed to touch. It looks like a screen protector, but isn't. However, it soon emerged that they were not alone in finding the Fold to be fragile, as reports worldwide emerged of screen failures after days of use. It seems the polymer layer removal is a separate issue, and something more serious was happening.

After investigation, Samsung has delayed the phone's launch. Something has gone wrong between the design, production, and testing, despite building a robot that opened and closed the phone 200,000 times to test the hinge. This is embarrassing, and has reminded everyone of the problems with Samsung's Galaxy Note 7 in 2016, the one that occasionally caught fire. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

✓ **5PB BLACK HOLE PIC**
The data used to generate the picture needed 1,000lb of HDDs, moved by airplane; the Internet would have been too slow.

✓ **AMAZON/GOOGLE PEACE**
The settled spat means we can look forward to YouTube on Fire TV Sticks, and Amazon Prime Video on Chromecast devices.

✓ **WIN 10 UPDATE CHOICE**
The upcoming Windows Update will finally enable you to choose when your machine updates.

TRAGEDIES

✗ **FTC LOOKS AT LOOT BOXES**
The Federal Trade Commission is to investigate the fairness of loot boxes, often seen as gambling.

✗ **NATIONAL PARK NO-NO**
The maker of a drone landed in hot water after a promo video was revealed to have been filmed in Yellowstone, a no-drone territory.

✗ **MICROSOFT EMAIL HACK**
A vulnerability in a customer support account has lead to hackers swiping people's email details and personal profiles.

Xbox Goes Disc-Free

MICROSOFT'S NEW Xbox One S All-Digital Edition has something missing: a disc drive. Other than that, it's an Xbox One S. The $249 box comes with *Minecraft, Forza Horizon 3,* and *Sea of Thieves* pre-installed, but pretty much obliges you to pay full price for digital downloads (no more borrowing or buying used). An Xbox Games Pass at $9.99 a month will get you a decent library of games, and you'll need another 10 bucks for an Xbox Live Gold subscription for the full multiplayer experience. The Xbox Game Pass Ultimate is due later this year at $14.99 a month, which includes both.

Going disc-free isn't a surprise—digital sales are now over 80 percent of all games sales. There isn't the money in making the console hardware either; getting people on a subscription is where the real payoff is. Microsoft is also working on a pure game streaming service, akin to Google's Stadia: project xCloud.

Meanwhile, we await the next generation of consoles, the Xbox Two and PlayStation 5, or whatever they're called when they arrive next year. Microsoft plans two new boxes, one a traditional console, the other designed to stream games, with some processing done locally, but the bulk of the game running on a cloud server.

Sony's new machine gets a custom set of silicon from AMD based around a Zen 2 Ryzen chip, coupled to a Navi GPU, which will support ray tracing. There's also a bespoke SSD system, which means minimal loading times. It all sounds good so far.

This pair will probably be the last generation of "traditional" consoles, where you can buy a hard copy of a game and actually own it. We should know a lot more about both after this year's E3 show. It's gearing up to be another head-on fight. **–CL**

New Ryzen Pro Chips

AMD
RYZEN
PRO

While we wait for AMD's Zen 2 core, the company is filling out its second-gen range. There are four new Pro mobile chips using the Picasso core, a 12nm Zen+ micro-architecture coupled with Radeon Vega graphics. All have a commendably low TDP of 15W. The best is the Ryzen 7 Pro 3700U, which boasts four cores, eight threads, and runs at a base clock of 2.3GHz, with a boost to 4GHz. Below this comes a Ryzen 5 Pro 3500U, similar but slower, and a Ryzen 3 Pro 3300U, which loses the multithreading. At the bottom we have an Athlon Pro 300U, with two cores, although this does get multithreading back. Nothing on pricing as we write. **–CL**

Microsoft Browser Goes Chrome

Microsoft has built its new Edge browser around the open-source Chromium code. Beta testers have been impressed. It has integrated Microsoft's technology neatly, and looks like something halfway between Edge and Chrome. It supports Chrome extensions, as well as having its own. It's also fast, something Edge struggled to be, and all the problems around visiting Google sites are gone. It has kept a good deal of Edge's power efficiency, and touchscreen abilities, too. It has also replaced or removed over 50 Google Services. Not quite the best of both worlds yet, but it's promising. **–CL**

AMAZON IS LISTENING TO YOU, LITERALLY

Does Alexa do more than obey your commands?

AMAZON HAS BEEN employing thousands of people to listen to recordings of other people talking to Alexa. They review up to a thousand recordings a day, transcribing the intended commands of people all around the world as they try to get Alexa to do what they ask. Approximately 10 percent of the recordings have been made when Alexa has been accidentally activated. Workers have heard all sorts of private details, from the mundane to a suspected assault. Inevitably, some recordings get passed around, either for clarification or because they're amusing.

Surprised? You shouldn't be. Alexa's translation service is powered by AI, which needs training, and the best way to do this is with a little help from humans. Understandably, Amazon has kept quiet about this "snooping." It claims it only uses a small sample of recordings taken after Alexa has been activated, they are chosen at random, and no identifying data is revealed. However, the recordings do have an account ID, and the device serial number, along with a first name, so not exactly anonymous.

Apple and Google are busy doing the same thing for their voice assistants. And this isn't the first time Amazon has been caught being careless with people's private lives; it did a similar thing with recordings made by "smart" doorbells.

When you invite Alexa into your home, you sign away the right not to be recorded, and used in a AI training session. You can opt out if you have the smartphone version, by choosing not to "Help Develop New Features" in the privacy settings. This should stop anything being passed on, but the wording is non-specific. **–CL**

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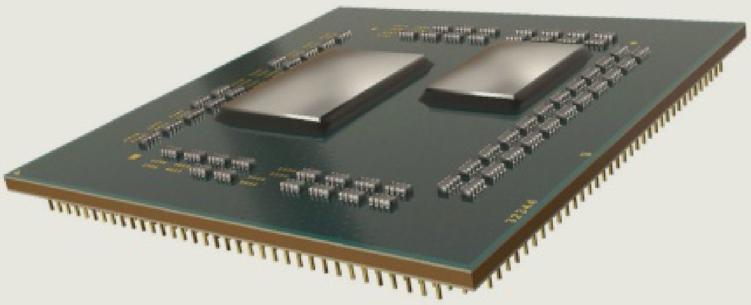

The next PlayStation will likely put the CPU and GPU into one package.

Sony's PlayStation 5 Is Even More PC

IT'S THE MIDDLE OF 2019, and Sony just dropped a bombshell and revealed many of the specs for its next-gen console, which we'll assume will be called the PlayStation 5. Even more surprising is the revelation that it's not coming in 2019, which means late 2020 instead. That's a long time to wait, but what will the next-gen consoles provide compared to PCs?

The current PS4 and Xbox One consoles (and their updated variant) already largely consist of hardware with its roots in the PC space, but the next iteration will further blur the lines. Sony is partnering with AMD again, moving from 2013-era hardware to the modern age. The heart of the PS5 will consist of an eight-core/16-thread Zen 2 (Ryzen 3000) CPU, with a Navi GPU that supports ray tracing, and an SSD for storage.

Both the CPU and GPU will use TSMC's 7nm lithography, and instead of a single custom chip, the PS5 will likely have separate CPU and GPU chips in a single package. Sony hasn't given details on the memory, but 16GB of GDDR6 seems likely—or possibly HBM2, but that would be more costly and isn't really necessary. Even with modern processors, however, Sony and AMD can only push performance within a console form factor.

Consoles are primarily designed for the living room, which means big boxes and massive power requirements are out of the question. Current consoles use 140–160W, about half of what a high-end graphics card requires. No one wants loud fans and tons of heat venting into an entertainment center, so I expect power use to fall below 250W, and even that's a bit high. What sort of performance could Sony wring from a 150–250W console?

Given the CPU and GPU are from AMD using its upcoming architectures, it's not difficult to guess at what we can expect. The Zen 2 CPU will be a substantial upgrade from the PS4's eight-core Jaguar design, and should be at least two times faster, probably more. The GPU will also be a significant upgrade, likely double the performance of the PS4 Pro—Sony claims 8K resolution support, but I assume that's for output (via HDMI 2.1), not that the console will manage 8K at 60fps. The Navi 20 architecture also adds support for hardware ray tracing, and as that feature will be present on all PS5s, it should see more uptake than Nvidia's first RTX cards.

I'm also excited to see Sony adding an SSD. It will be some form of NVMe storage, based on early storage performance claims, but capacity hasn't been disclosed. Perhaps Sony will use an SSD caching solution, however, as games are becoming quite large. Sony could just stuff in a 1TB SSD, but that will increase the cost.

All this sounds good, but it's basically just a specialized PC running Sony's OS. At least it will be backward compatible with PS4 games. I don't expect it to be a massive upgrade compared to a modern PC. In fact, given the likely TDP, it will probably end up with performance similar to a Ryzen CPU with an RTX 2060 graphics card. That's what happened with the PS4 as well: Rather than matching a high-end PC, it was more like the previous year's mid-range PC, with a reasonable price.

> It will probably end up with performance similar to a Ryzen CPU with an RTX 2060.

The early announcement of the PS5 hardware again emphasizes how the PC is the leader in pushing hardware and software. PCs have led the transition from physical media to digital downloads, and storage is moving away from spinning platters to SSDs. Special-purpose processors like the PS3's Cell have been supplanted by generic x86 CPUs. And as for graphics, PCs have had ray-tracing GPUs from Nvidia for nine months already, and it will be two years by the time the PS5 arrives.

None of this is surprising. Researching and creating new, higher performance processors takes time and money. It's possible to create new architectures that might be a bit faster than PCs already have, but is it worth doing? Sony apparently doesn't think so, and Microsoft will probably take a similar approach. We're all just one big PC family now—except the consoles are locked down, so you can't easily install your own OS.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

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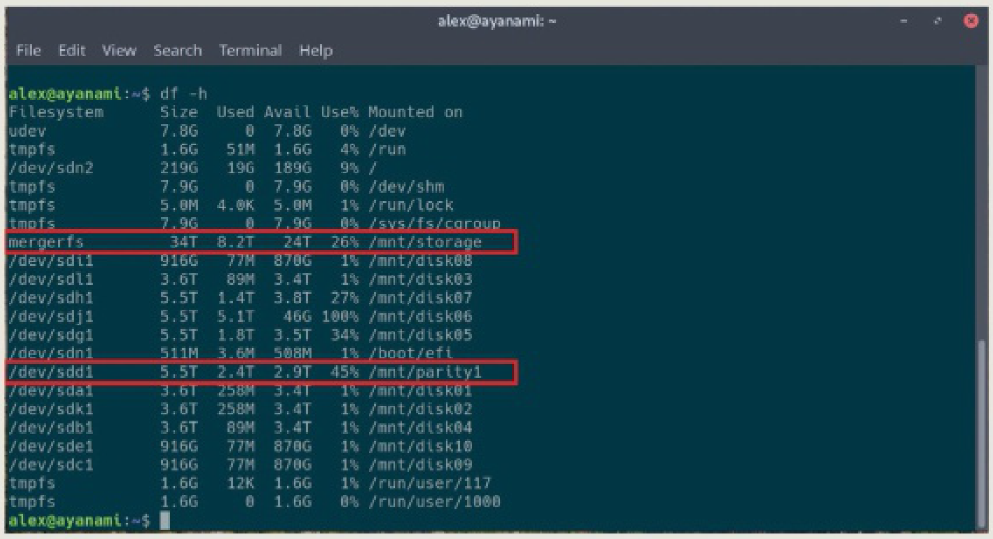
OPEN SOURCE

Do You Need Traditional RAID in Your Server?

DATA HOARDERS REJOICE: If you're building a home server, you're not constrained to using traditional JBOD, RAID, or RAID-Z. SnapRAID and MergerFS offer JBOD-like storage advantages with the data security you'd expect from RAID 5. For most home users, the performance is more than enough. And you'll be able to use heterogeneous drives to boot.



```
alex@ayanami:~$ df -h
Filesystem      Size  Used Avail Use% Mounted on
udev            7.8G     0  7.8G   0% /dev
tmpfs           1.6G   51M  1.6G   4% /run
/dev/sdn2       219G   19G  189G   9% /
tmpfs           7.9G     0  7.9G   0% /dev/shm
tmpfs           5.0M  4.0K  5.0M   1% /run/lock
tmpfs           7.9G     0  7.9G   0% /sys/fs/cgroup
mergerfs         34T  8.2T   24T  26% /mnt/storage
/dev/sdi1       916G   77M  870G   1% /mnt/disk08
/dev/sdl1       3.6T   89M  3.4T   1% /mnt/disk03
/dev/sdh1       5.5T  1.4T  3.8T  27% /mnt/disk07
/dev/sdj1       5.5T  5.1T   46G 100% /mnt/disk06
/dev/sdg1       5.5T  1.8T  3.5T  34% /mnt/disk05
/dev/sdn1       511M  3.6M  508M   1% /boot/efi
/dev/sdd1       5.5T  2.4T  2.9T  45% /mnt/parity1
/dev/sda1       3.6T  258M  3.4T   1% /mnt/disk01
/dev/sdk1       3.6T  258M  3.4T   1% /mnt/disk02
/dev/sdb1       3.6T   89M  3.4T   1% /mnt/disk04
/dev/sde1       916G   77M  870G   1% /mnt/disk10
/dev/sdc1       916G   77M  870G   1% /mnt/disk09
tmpfs           1.6G   12K  1.6G   1% /run/user/117
tmpfs           1.6G     0  1.6G   0% /run/user/1000
alex@ayanami:~$ 
```

Storage mounts on a server; note the MergerFS volume and parity drive.

To keep costs down when building a home server, it's a good idea to make use of any existing hardware you have. But one of those hardware requirements may warrant thought: the hard drives.

The first thought you might have is to create a traditional RAID or RAID-Z array. Those solutions are fine, but if you think about it, a traditional RAID array has a few requirements that aren't great.

First off, RAID arrays require all the hard drives to be up and spinning for any read or write operation. This alone has consequences, one of which is energy use. Sure, a few watts may not sound like much, but when drives are spinning 24/7, it can be like leaving several 60W light bulbs on all the time, and this can add up.

Heat becomes a problem as well. I ran my home server with five drives in a RAID 5 array for a long time, with the server in my home office. Sacramento summers can be hot, and having five spinning drives up all the time made the room unbearable. Along with heat comes noise. Keeping drives cool means running fans all the time.

When I decided to rebuild my server in October, I looked for another method that would maximize my storage while maintaining a level of data security (through RAID 5-like parity). I stumbled across SnapRAID and MergerFS, which is what I run now.

SnapRAID with MergerFS is a little like a JBOD (just a bunch of disks) array in disguise. MergerFS operates on top of a drive's filesystems, and allows you to use your drives as a single logical drive. SnapRAID handles parity and backup operations, so you can restore data if a drive fails. You'll have to do this through snapshotting, however.

From a cost perspective, this is great. With typical RAID arrays, it is recommended to use identical drives. With SnapRAID and MergerFS, I could take my 5TB drives and add a couple unused 4TB and 1TB drives.

SnapRAID also only has to spin up one drive at a time for file access. This can save life on your drive motors, keep energy use down, and reduce heat. SnapRAID attempts to fill one drive at a time, too. This means that unused drives largely stay at rest until needed. The bad thing about this, of course, is that one drive may be taking the brunt of access requests.

One of the downsides of using SnapRAID/MergerFS is that reads aren't as fast as traditional RAID. But if you're using the machine as a server, there's a good chance that your gigabit network is saturated by the reads from a single drive anyway. If you're accessing your server over the Internet, your upload speeds dictate your read performance as well. Basically, outside of having a 10Gb network, SnapRAID/MergerFS perform just fine for most home networks.

If you're looking to build a server, take a look at SnapRAID (free software under GPLv3) and MergerFS (open source under the MIT-like ISC license). If you decide to try it, there's a great guide from LinuxServer.io (https://blog.linuxserver.io/2017/06/24/the-perfect-media-server-2017/).

Alex Campbell is a Linux geek who enjoys learning about computer security.

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THE LIST

MOST EXCITING THINGS AT GDC 2019

8

FMOD 2.0 RELEASE Firelight Technologies released the much-awaited 2.0 update to its game audio creation software FMOD.

7

Keith the Wizard
"what about just the ones that are swords"
ITEM
VALUE
WEIGHT
Keith the Wizard
"These are all of the inexpensive swords I have."

CLINC NATURAL LANGUAGE AI Conversational AI developer Clinc announced its new in-game AI companion, capable of picking up slang and contextual words.

6

EVASYST EARLY ACCESS A new all-in-one gaming communication app, Evasyst, was brought into early access before a full reveal at GDC.

5

OCULUS RIFT S Oculus is still pushing its VR headsets, with the S poised to be a straight upgrade to the original Rift.

4

UNITY ANNOUNCES AR FOUNDATION INITIATIVE An initiative from Unity enables developers to target both the ARKit and ARCore platforms more easily when producing augmented reality games.

3

HP REVERB ANNOUNCED Bumping up the resolution to hitherto unseen levels could put HP's new VR headset at the front of the pack.

2

EPIC MEGAGRANTS PROGRAM *Fortnite* creator Epic Games pledged a whopping $100 million in grant money for the development of new games.

1

GOOGLE STADIA Google's new cloud gaming platform was the biggest news, with a natty Wi-Fi controller to boot.

HEAD TO HEAD

BY **CHRISTIAN GUYTON**

Thunderbolt vs. USB

When it comes to transferring data and power, choice of bus is king. The battle between aging champion Universal Serial Bus and plucky new contender Thunderbolt has been an exciting one to watch, and now we're here to put it to bed—for a little while, at least. USB might have had more time to integrate itself into as much technology as possible, but Thunderbolt from Apple and Intel is hot on its heels, and both have their advantages and failings. Which is truly superior, though? Let's take a look....

ROUND 1

Value

Our first showdown is easy: It's USB, without a doubt. Even the more recent 3.1 and 3.2 iterations aren't much more expensive than USB 3.0, affordable both for manufacturers to implement and for consumers to purchase—USB drives and cables are almost ubiquitous now, an open platform usable by just about anyone. Thunderbolt, on the other hand, was created as a joint venture between Intel and Apple, and still requires certification from Intel for manufacturers to use. The initial connection with Apple may have harpooned Thunderbolt from the start, if the tech giant's pricey history with its proprietary Lightning connectors is anything to go on, anyway.

Both buses require purchase of control chips for hardware developers, but USB is cheaper, and doesn't require accreditation from Intel to implement. While Thunderbolt 3 and USB-C use the same connector model—meaning that Thunderbolt 3 cables and devices can connect to a computer with a USB Type-C port—to ensure compatibility, manufacturers must shell out to add Thunderbolt tech to their hardware to reach the higher speeds it offers. USB might not be as powerful or flashy as Thunderbolt, but when it comes to examining consumer demand, it offers greater satisfaction against cost.

Winner: USB

ROUND 2

Performance

It's hard to argue that USB can outperform Thunderbolt. Looking at the most recent iterations of each (USB 3.2 and Thunderbolt 3), Thunderbolt blows USB out of the water by offering a super-fast 40Gb/s via two aggregated bi-directional channels, in comparison to USB 3.2's 20Gb/s. USB's 3.2 version (confusingly referred to as 3.2 Gen 2x2) still hasn't reached proper market penetration, though, so USB 3.1 and 3.0 are the current popular standards, which only offer 10Gb/s and 5Gb/s respectively. Some motherboards still ship with USB 2.0 ports, which are only capable of 480Mb/s. Thunderbolt 3 is ideal for daisy-chaining devices, too, but every device must be Thunderbolt-compatible; adding a DisplayPort or USB device ends the chain there.

Both current versions can feed DC power both ways at the same maximum rate: 100W for mains system power; 15W for device or peripheral charging from a "master" system. These are theoretical maximums—actual power supply alters based on many factors, such as available power or cable, and connector quality and type. Power supply doesn't impact on data delivery speeds in either format. While USB 4 might be on the horizon, promising Thunderbolt 3-level speeds, right now it's a clear win for Thunderbolt.

Winner: Thunderbolt

ROUND 3

Versatility

USB is everywhere. It's a staple of modern tech, a well-established standard. Thunderbolt 3 is a superset of USB, but is far from seeing the same widespread use. Part of this is due to USB's history. Seven companies—including Intel and Microsoft—banded together to create a new standardized interface. As such, USB has always been versatile and effective, connecting everything from interactive peripherals to speakers, monitors, and drives. Thunderbolt is more purpose-built; ideal for daisy-chaining monitors or downloading data to external drives.

Flash drives with native Thunderbolt interfaces are rare; drives that connect via a Thunderbolt 3 cable are more common, but expensive. Type A USB-connector thumb drives are common, with USB-C versions becoming more popular. USB-C is compatible at full speed with Thunderbolt 3 ports, while the reverse is not the case.

Copper versus optical cabling was an interesting debate in the early years of Thunderbolt. All versions of USB have used copper, limiting maximum range to five meters. Thunderbolt 1 and 2 utilized optical cables to reach maximum lengths of 60 meters, but this functionality was discontinued for Thunderbolt 3—although using adapters, it can still be managed.

Winner: USB

HEAD

ROUND 4

Future

USB has existed for over 20 years. It's not going anywhere, but it's also not moving forward at any speed. USB 4 was recently announced, promising Thunderbolt 3 speeds, and the USB Implementers Forum (USB IF) is committed to keeping the interface updated; hence the numerous editions of the third series—that's right, USB 3.2 Gen 1x2 and USB 3.2 Gen 2x2 are subtly different. Extremely subtly. USB lives up to the "universal" in its name, having had far more time than Thunderbolt to beat out competitors and become the industry standard for data and power connections.

Thunderbolt has existed for eight years, but spent the better part of this time serving as a display and power interface for Apple products, primarily MacBook and iMacs, where Thunderbolt 1 could be used for daisy-chaining monitors. The tech went mainstream with Thunderbolt 3, thanks to the adoption of the USB-C model, but the requirements for manufacturers to support Thunderbolt formats may not bode well, particularly with USB 4 being able to match its speeds without demanding additional control hardware. Thunderbolt 3 is an Intel property, too, which means no AMD chipsets or computers support it, with no plans in sight for compatibility.

Winner: USB

ROUND 5

Simplicity

From a manufacturer's standpoint, USB formats are easier to implement and familiar to consumers, particularly with the introduction of the USB-C connector, which can be inserted either way up—finally catching up to Apple's Lightning connectors. The traditional USB connector, running up to 3.2, is a recognizable staple of technology for consumers everywhere. USB ports have the potential for color-coding for easier identification, given the numerous variations on the format.

However, USB's open design let hardware producers create many versions of USB port—DAC-focused ports for speakers and headphones, for example, provide superior sound quality to a conventional USB port. Thunderbolt's closed design benefits it here; there is no variation, so every port delivers maximum performance.

The variety of connectors is more refined with Thunderbolt; 1 and 2 used a Mini DisplayPort connector, while 3 adopted USB-C. USB might be moving toward USB-C as a standard, but still has too many different connectors. The Type A connector is common, but there are still many devices that use outdated Mini and Micro variations—the Micro-B SuperSpeed connector was supported all the way up to USB 3.0, and is horrible as connectors go.

Winner: Thunderbolt

And the Winner Is...

This feels unfair, but the numbers don't lie: USB went three for two up against Thunderbolt, and thus must be declared the winner. Thunderbolt might be the faster, sexier version, but the fact remains that it owes its very existence to USB. Will Thunderbolt—perhaps the as-yet unannounced Thunderbolt 4, presumably faster than anything seen before it—become the standard for buses in the future? Possibly. But looking at the state of things, it's hard to picture that world.

USB might not be as fast, but the USB IF knows this; with Thunderbolt 3's protocol specs made public in March, USB 4 was swiftly announced to match it. With the sheer prevalence of the Type A connector, USB may have reached market penetration to the point where nothing can unseat it. The low cost of USB peripherals, cables, and drives makes it the most popular choice, and unless Intel can drive down the costs associated with Thunderbolt, it doesn't seem likely that it could overtake its competitor. It's had two decades to establish itself as the gold standard for bus interfaces, so USB isn't going anywhere anytime soon.

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> Display Dilemmas
> Superb Solid State
> Box-Fresh Windows

Maximum PC(Ie)

Hello Doc, I'm gearing up to build a workstation that will have dual use: 2560x1440 gaming and VR (on an Oculus Rift with three Oculus Sensors, which require USB 3.1), and for data science. I'm considering AMD's Ryzen Threadripper and Intel's Core i9-9900K. What are the real-world implications of the 64 PCIe lanes on Socket TR4-based motherboards versus the 24 lanes offered by the Z390 platform?

In theory, Threadripper should be far superior. I can have a 16-lane graphics card, two M.2-attached SSDs in RAID, a four-lane 10Gb/s Ethernet controller, and a four-port USB add-in card, all fed by the host processor. With a Core i9, once I drop in the graphics card and one SSD, connectivity on Intel's chip is maxed out, and everything else needs to funnel through the chipset's paltry four-lane DMI. How much will performance differ between the two, though? It seems like Threadripper is better suited to VR because of the connectivity required by those Oculus Sensors.

Also, is it even worth considering on-board 10Gb/s Ethernet or Thunderbolt 3 for non-X-series Intel CPUs, since everything on the motherboard has to be jammed through DMI, including the networking controller, all USB ports, and Thunderbolt 3?

–Marc Mackey

V-NAND SSD
970 EVO Plus
NVMe M.2
SAMSUNG
www.samsung.com/ssd
SAMSUNG ELECTRONICS CO., LTD.
2TB

Samsung's 970 EVO Plus utilizes 96-layer V-NAND and firmware optimizations to beat every other TLC-based SSD on the market.

THE DOCTOR RESPONDS: Comparing the connectivity available from AMD's high-end desktop platform to Intel's "mainstream" Z390/Z370 chipsets definitely favors Ryzen Threadripper. It would be fairer to consider the Core X-series CPUs and their complementary X299 platform, though that combo still doesn't offer as many PCIe lanes as AMD's chips.

How much difference does Intel's deficit make in practice? It depends on your workloads. Of course, gaming puts an emphasis on your graphics card and its x16 slot (or even two cards sharing 16 lanes via x8 links). VR isn't much different. It's a GPU-limited task with some I/O over USB in the case of Oculus's original Rift. Either way, you aren't held back by connectivity, and Intel's architecture even enjoys an advantage for its ability to do more work per core, per clock cycle. Plus, the upcoming Oculus Rift S only needs one USB 3.0 port for its Insight tracking system, which employs five cameras on the headset itself.

Data analysis through GPU-accelerated algorithms is also going to fully utilize your graphics card. But that segment benefits from gobs of system memory and fast storage, too. The Doc uses a 1.6TB SSD DC P3700 on his machine-learning test bench, which ties up four lanes of PCIe 3.0. When you tack on a fast networking controller, a 40Gb/s Thunderbolt 3 controller, and add-in USB connectivity, it's easy to see how the link between Intel's host processor and Platform Controller Hub becomes a theoretical bottleneck.

Do you expect full utilization from all those devices concurrently, though? It would be rare to see a couple of high-end SSDs maxed out at the same time as an Ethernet controller, for example. In most applications, available PCIe connectivity won't hold you back. Intel's Core i9-9900K is generally adequate (and potentially less expensive) in those situations. But it will limit your ability to expand as you scale up horsepower for data science. Co-processors to accelerate deep learning, whether they're GPUs, ASICs, or FPGAs, need PCIe slots. That's going to be an issue for Intel's Z390/Z370 chipset.

Blast from the Past

Hi Doc, Please accept all applicable accolades for an excellent magazine. I have a quick question. I've been

↘ submit your questions to: doctor@maximumpc.com using an NEC 3090WQi monitor for years, and it was well worth the two grand I spent on it. But it's starting to show its age (as am I). After being left on all night, the display starts showing a strange shadow pattern. If I turn it off, it works fine. Unfortunately, I have a bad habit of leaving the monitor and PC turned on, so I believe it's time for a replacement.

Here's the thing: I'm having a difficult time finding an equivalent 30-inch or larger monitor with a similar vertical pixel count, and I don't want a worthless toy with a 16:9 aspect ratio when I have 16:10 now. Do you have any suggestions? I just heard about the new Alienware 55-inch OLED panel, but I think that's a bit too large for a desktop PC. Thanks, from one doc to another.

–Robert Kleinhaus, MD

THE DOCTOR RESPONDS: Once upon a time, the Doc used a trio of 24-inch Dell 1920x1200 displays for writing, research, and gaming. As they grew older and needed to be replaced, he was dismayed by the shift to 16:9, since a loss of vertical screen space meant more scrolling through white papers and reviews spanning many thousands of words. At least there was some solace in lower prices, enabled by manufacturing efficiencies as TVs and monitor panels shared the same aspect ratio.

But based on your interest in the Alienware 55-incher, which employs a 4K OLED panel able to refresh at 120Hz, it sounds like you're more concerned about absolute resolution than maintaining a specific aspect ratio. After all, 3840x2160 translates to 16:9, just like 2560x1440.

The Doc agrees that 55-inch is too large for a typical desktop environment, where you sit a couple of feet away from the screen. So, why not consider a 4K screen in the 30 to 32-inch range? You'll find plenty of options for less than $1,000, and a handful of professional models available between $1,000 and $2,000.

If you really must have a 2560x1600 resolution, Dell's UP3017 is still for sale direct from the factory. NEC's old PA302W is around in some capacity, too. However, both monitors are more expensive than a lot of really nice (and newer) 4K screens.

Upgrading a Dinosaur

Hi Doc, I need a little advice. I have an Asus M4A785TD-V-EVO motherboard and an AMD Phenom II processor. I'd love to drop in a new CPU for some additional performance and, at the same time, keep all of the old components.

If this isn't possible, I'm willing to buy a new motherboard to support a newer AMD processor if it means I can also recycle the hardware plugged into my existing system, which I built with the help of your magazine a few years ago.

–Ed

THE DOCTOR RESPONDS: The AMD 785G chipset on your M4A785TD-V launched almost 10 years ago. According to Asus, its mobo accommodates everything up to a Phenom II 1100T—the highest-end six-core model AMD made. You might be able to find a used one, but it would almost certainly cost more than you should spend on 10-year-old technology. Don't do this.

A Socket AM3+-equipped platform would at least let you keep the same DDR3 memory, graphics card, and storage subsystem. Stepping up to a motherboard with an AMD 970 chipset and an eight-core FX-8350 CPU wouldn't even cost very much. But again, you'd have to accept spending money on hardware introduced in 2012.

Try this on for size instead: Snag an affordable AMD B450-based motherboard, an inexpensive Ryzen 3 or Ryzen 5 processor, and at least a couple of 4GB DDR4 memory modules. Old graphics cards, SATA hard drives or SSDs, and other PCIe peripherals should carry over without a problem if you don't plan to buy new ones. But you'll own a modern platform with conveniences such as USB 3.1 Gen 2 and a clear upgrade path.

Cutting-Edge SSDs

Doc, I'm considering buying two Samsung 970 PROs, namely a 1TB model for data storage and the 512GB version for installing my Windows 10 operating system. But your April 2019 article on the Samsung 970 EVO Plus 1TB now has me reconsidering.

The benchmarks show the 512GB 970 PRO lagging behind the 1TB 970 EVO Plus 1TB, which the article explains by saying "platform differences may account for some of the delta." Can you please elaborate?

Putting aside the Intel 905p because of its price, should I swap the two 970 PROs I'm considering for a pair of 970 EVO Pluses?

–Robert Tortorelli

THE DOCTOR RESPONDS: Go with the 970 EVO Plus. Samsung's first SSD with 96-layer V-NAND improves upon its predecessor while maintaining the original 970 EVO's price points. As a result, the 970 EVO Plus offers performance per dollar that's hard to beat.

The 970 PRO does employ two-bit-per-cell NAND, which turns in better benchmark numbers than the 970 EVO Plus's V-NAND in its native TLC mode. But Samsung gives the 970 EVO Plus a generously sized single-level cell cache, so it can sustain sequential read and write speeds that bump against the limits of a four-lane PCIe 3.0 link.

And don't worry about the endurance of Samsung's V-NAND. Not only is the company known for selling reliable SSDs, but it covers the entire 970 EVO Plus family with a five-year limited warranty. The 500GB model is rated for 600 terabytes written, while the 1TB version boasts a 1,200 TBW rating.

Resetting Windows 10

Hi Doc! My eight-year-old system is showing its age to the point that I want to replace it. Although everything runs well, I'm not sure how much longer it'll last. I was thinking about giving it to a friend so that one of his enterprising kids can tinker with it.

I'm currently running Windows 10 Home and will get a fresh license with the new machine. I have no problem removing all my personal files before handing the PC over, but now that so much of Windows is tied to online accounts and web services, is there an easy way to depersonalize an installed copy of Windows 10?

It's not worth the effort for me to format the hard drive, reinstall Windows, and load up fresh drivers, nor do I want to leave this task to my friend. So, I was hoping you knew of a relatively painless way to clean everything up. Can I set up a new admin account under the recipient's name and use that to delete the one under mine?

Also, since so much of my personal info is tied to Google nowadays (as it covers both my PC and phone), if I uninstall Chrome, will that erase my Google profile from the system, or are there additional steps I need to take to secure non-Microsoft products and services?

–Isaac Peterson

THE DOCTOR RESPONDS: There's no need to erase profiles or hand-pick the accounts to delete. Simply open the "Start" menu, click the "Settings" icon, and select "Updates & Security." In the left-hand pane, click "Recovery," and under "Reset this PC," click "Get started." When the new window opens, select "Remove everything" and follow the instructions to get Windows 10 back to a "factory" state.

SO RETRO!

We asked *John Knight* to relive the entirety of computing history through open source. He almost died trying...

SCORE 01 HI SCORE 0129 CREDITS 01
TUX81

NEVER HEARD OF EMULATION? It's when a piece of software mimics another machine in order to run its programs. For instance, you may have seen someone playing old Nintendo games on an Android phone. Emulation is best known for its use in playing old videogames on modern systems, but it's used in many areas of computing, with many different purposes.

The first emulator was developed by IBM in 1965, for the System/360 line. It could run programs written for the older 7070 system, and was a hit with customers. Although emulation would continue to develop in the computing industry, it remained relatively niche until the '90s, when game console emulation on PCs resulted in landmark court cases. Nowadays, emulation is mainstream, and is used for everything from virtual machines to nostalgic consoles, such as the Nintendo Classic Mini.

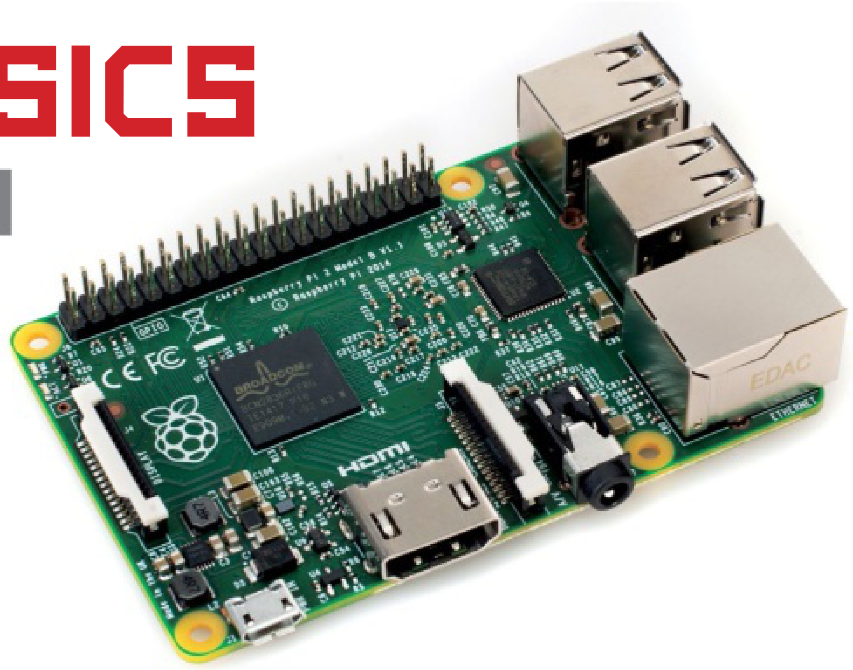
Emulators can be described as having anything from low-level to high-level emulation. The lower the level, the closer it is to the hardware, and the more system functions it tries to replicate. The higher the level of emulation, the more it simply mimics the required output behavior (for instance, "open a file" or "draw a rectangle on screen").

The more it emulates the original machine, the more accurate the program's behavior, but at a cost of speed, as your computer has more to process. The higher the level of emulation, the better the performance, as your computer can use its own hardware more, but at a cost of accuracy. The program is more prone to errors, and feels less like the machine being imitated, and more like the system it's actually running on.

Emulators are particularly useful in getting around digital obsolescence. A business may rely on a niche piece of software, or a videogamer may want to play something from older systems on their current machine. In previous decades, major game companies have tried to stomp out attempts at emulation, but now that it's become so pervasive, some companies have started embracing the technology, and integrating their old software libraries into online stores—often applying visual upgrades in the process, such as higher resolutions.

EMULATION BASICS

What's inside the box? Another box...



The Raspberry Pi's power and diminutive size made it an instant hit on the emulator scene—a Pi Zero even fits inside a NES controller.

OTHER THAN THE EMULATOR, you usually need two things: some ROMs and a BIOS. "ROM" is a blanket term for programs you want to emulate. Although it should refer to an image of a system's Read Only Memory chip, it is often used in the context of normal disk images that can be altered. Either way, you search for ROMs on specialist ROM sites. The BIOS is another blanket term for the program responsible for controlling the machine.

Distributing ROMs is generally illegal, unless there's a license that allows it—the exact legality varies between territories. Dumped copies of a system BIOS are legal under US law as long as the user owns the original machine. As you will see later, some emulators have their own substitute BIOS, which anyone can use legally and for free, developed through a process of reverse-engineering, though usually at a cost of emulation accuracy.

SOME WINE?

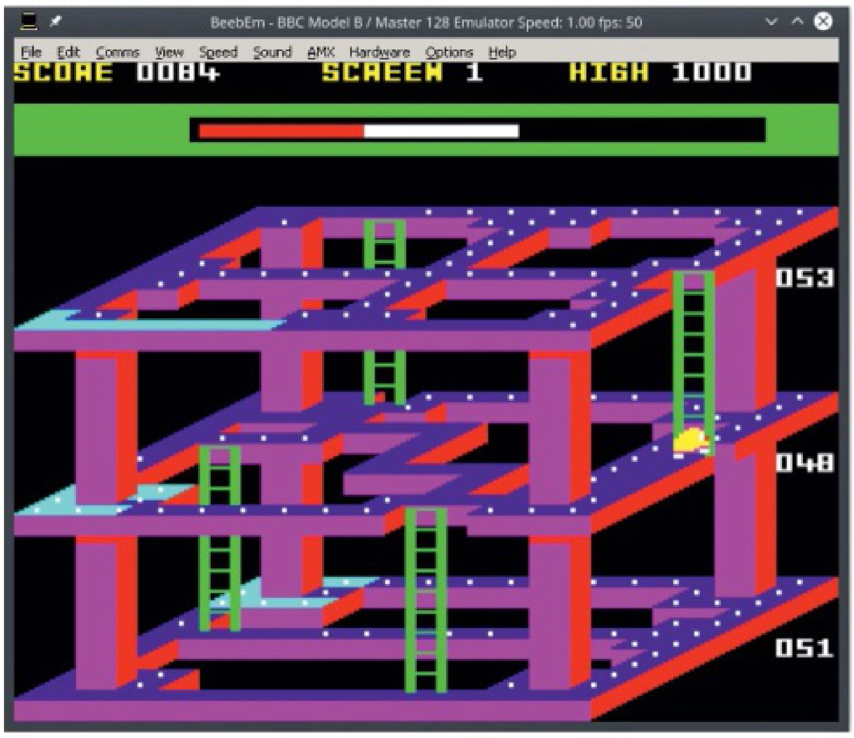
If you've used Linux for any decent length of time, you'll have come across Wine. Wine lets you run Windows programs on Linux, but as any smarty-pants will tell you, Wine stands for "Wine Is Not an Emulator." So what is it, then? Wine is what's known as a compatibility layer. Compatibility layers take system calls from the foreign application and translate them for the native system.

For instance, if you're running Microsoft Paint and click the maximize button, it sends a signal to the OS (a system call) to maximize the window. If you were running Paint in Linux with Wine, when you click the maximize button, Wine simply takes that Windows system call and substitutes it with a Linux system call.

The result is that rather than running a program under a Windows emulator, you are running the program natively as a Linux application—the main benefit being speed. Compatibility layers don't stop there. Another variant is what's known as a wrapper, which translates one kind of driver API into another.

For instance, in the late 1990s, 3dfx Voodoo cards were extremely popular for 3D acceleration. Although these cards supported OpenGL and Microsoft's Direct3D, 3dfx had its own proprietary Glide API that would guarantee the best performance with its hardware. This is often called a wrapper.

With its deep pockets, Valve was able to build upon the existing Wine codebase with its own functionality. By changing from OpenGL to the new Vulkan API, Valve implemented huge performance gains, making conversion between Microsoft DirectX 12 and the Linux desktop genuinely viable. Although it's still relatively early days, around 53 percent of Windows games work so far, giving Linux gamers an enormously increased library.


BeebEm - BBC Model B / Master 128 Emulator Speed: 1.00 fps: 50
File Edit Comms View Speed Sound AMX Hardware Options Help
SCORE 0084
SCREEN 1
HIGH 1000
053
048
051

Emulators: Software running inside hardware running on software—it's like *Inception* for computers!

MAME AND GAME

It would be remiss of us not to mention the colossus that is MAME—the Multiple Arcade Machine Emulator. The hardware of older arcade machines could vary wildly between games, so an emulator was needed that covered all these different machines.

MAME differs from other emulators in that it uses a modular approach, where individual cores are installed that power and control different machines. This approach is an effective new path that may prove more reliable than constantly writing new emulators with different interfaces.

MAME has been around since the 1990s, and is command-line driven, so you'll want a GUI front end for it; MESS has been on the scene for ages, but RetroArch is now the most popular.

RetroArch is probably in your Linux distro's repository, but if not, check the instructions at www.retroarch.com for multiple installer options. To save time and avoid frustration, choose the Development version over Stable. If you choose the Stable version, you may not have the Core Updater function, which is where you can choose from a large list of regularly updated emulation cores.

However, not everyone is a fan of RetroArch—it can require a lot of tinkering, and may mess with your control layouts. If you fancy an alternative, try Attract-Mode (http://attractmode.org)—it's a newer front end that is still open source, but has a strong community behind it, and support for scripting.

COMPUTING PRE-HISTORY

Defining the earliest "computer" is tricky, but they've certainly been around for longer than you might think

ONE OF THE EARLIEST MACHINES to be accepted as an analog computer is the Antikythera Mechanism. Dated to around 100 BC, it was used in astronomy to determine the positions of celestial bodies decades in advance. Only fragments of it remain, but detailed imaging suggests it could even model the irregular orbit of the moon. You can find a simulation of the Antikythera Mechanism at www.etl.uom.gr/mr/index.php?mypage=antikythera_sim. It only has a Windows executable, but it runs under Wine.

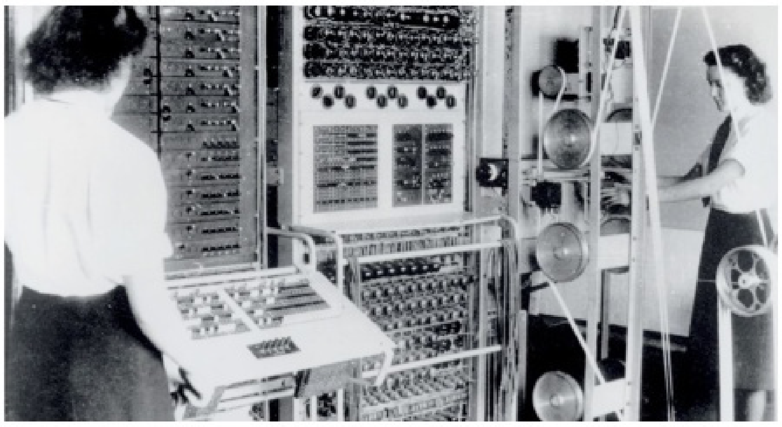
In the 13th century, we find Turkish inventor Ismail al-Jazari and his automata, laid out in his *Book of Knowledge of Ingenious Mechanical Devices*. Al-Jazari made complex mechanical musicians that ran via clockwork, and even had a programmable drum machine, coded by altering the movement of cams. However, documentaries usually start just before the Victorian era. In those days the word "computer" would have evoked an image of a guy with a pencil behind his ear doing math. But these squishy creatures were unreliable at best, and a machine with unerring accuracy was needed for a genuine technical revolution.

WHERE'S ALAN TURING?

Babbage's machines were analog, but for digital computers, history usually looks to Alan Turing. You probably know the story well—how Alan Turing cracked the Germans' Enigma code so that Benedict Cumberbatch could save England (according to the film *The Imitation Game*). But this simplified version of events gives the impression that Turing was behind all the computer design and Nazi code-breaking. That's not really the case. The Enigma codes were indeed broken with the aid of a machine called the Bombe, designed by Turing and Gordon Welchman, thus helping to defeat the German navy.

The ultimate target was the coding for the more advanced Lorenz machine, used by the German high command, and even Hitler himself. Although Turing influenced what was built, it was actually an unsung hero, telephone engineer Tommy Flowers, who was behind the design and construction of Colossus—and out of his own pocket, no less.

The computer needed to be built using valves and switches. This made it enormous—as big as a room—presumably leading to its name. With the first model being built in 1943, the Colossus is regarded as the first programmable digital electronic computer. You can run your own online at www.virtualcolossus.co.uk.



A Colossus Mark 2 being operated by British Wrens.

SPLIT THE DIFFERENCE

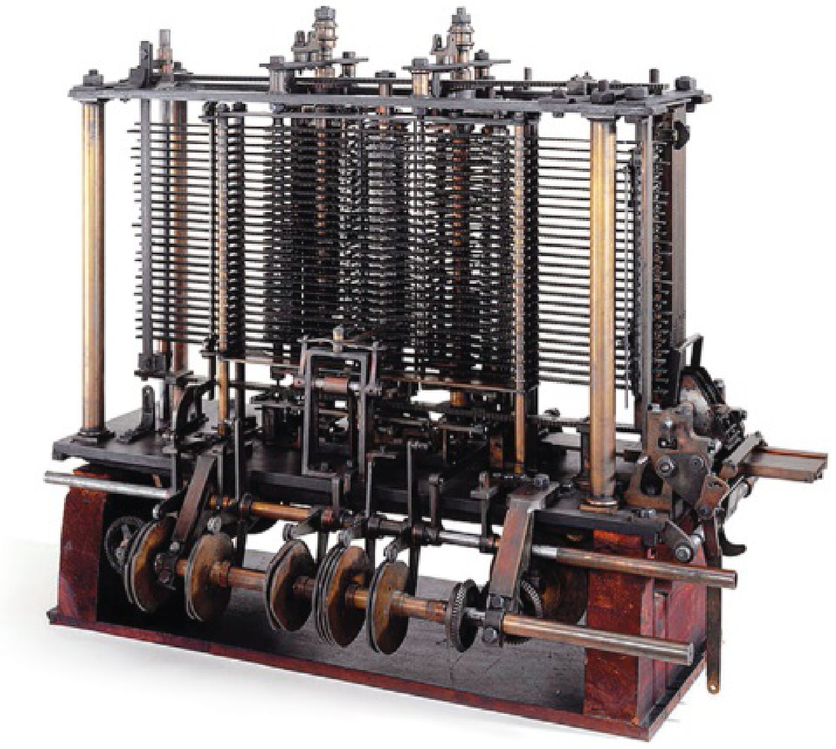
Enter Charles Babbage (1791-1871) and his Difference Engine. This was a mechanical number-cruncher, powered by a hand crank, with digits shown on rotating dials. It could not only perform arithmetic, but could also be programmed to follow numeric sequences, and even extract the root of a quadratic equation.

Babbage also designed the Analytical Engine, though it was never built. This would have been so far ahead of its time that it's almost scary, with features much like a mainframe computer of the mid 20th century: punch-card programming, 16.2K of decimal storage, a grid layout with its own internal procedures, like a CPU dubbed "The Mill," and something akin to assembly language.

Unfortunately, withdrawn funding meant the Difference Engine was never completed (Babbage only made a stripped-down prototype), and there was no interest in producing the even more elaborate Analytical Engine. Nevertheless, enough design existed for Babbage's friend Ada Lovelace to write an algorithm for it, thus Lovelace is generally credited as having written the first computer program.

Victorian Britain may not have been interested in completing the Difference Engine, but thankfully modern Britain is. If you want to try out the Difference Engine, there are some simulations online, and a Python script on GitHub if you want to look for them. If you want to see it in the metal, as it were, the Science Museum in London has an operational section on display. Meanwhile, the Analytical Engine is currently being built by the Plan28 organization—see http://plan28.org for more info.

Imagine your processor starting a calculation on one side of the room and finishing on the other, all run by cogs.



THE MAINFRAME IN THE ROOM

Awarding the title for "first videogame" is also tricky, and generally depends on who you believe—but here's a rough guide...

ALTHOUGH THERE ARE PLENTY of contenders, generally the entry that gets awarded without controversy is 1958's *Tennis for Two.*

An astonishing technical achievement, the title suggests something like *Pong,* but the reality is far grander. Designed by American physicist William Higinbotham, it was built over three weeks using a modified oscilloscope. Whereas *Pong* has a simple top-down viewpoint, *Tennis for Two* is viewed side-on, and has real-time physics, with gravity and inertia shaping the game's dynamics. There is a simulation you can run on your PC, but don't bother with that. Just search for it on YouTube, and watch it being played on an oscilloscope—it's an exquisite piece of engineering that makes the likes of Atari look positively vulgar.

However, these were one-off machines. The first known game to be copied and installed on multiple machines is *Spacewar!* from 1962. Written at MIT for the DEC PDP-1 computer, it has two spaceships engaged in a torpedo dogfight while avoiding the gravity well of a star. In order to get around the physical awkwardness of two players on a keyboard, it had an early form of gamepad. Other features include random starfields, the wrap-around effect when you cross an edge of the screen (later famous in *Asteroids),* and even a warp feature for random teleportation.

Note that *Spacewar!* is often confused with 1969's *Space Travel,* particularly by Unix fans. *Space Travel* was an early space-flight videogame developed for the PDP-7 that had the player flying around a scale model of the solar system. The development process of the game and the technical constraints imposed upon Ken Thompson led to the push to create a better system, which resulted in Unics, or Unix*, as it's known today

Spacewar! became so influential that it spawned two arcade machines in 1971: *Galaxy Game* and *Computer Space.* These were two of the very first arcade machines, the latter being the first commercially available videogame. A second videogame market was developing in the form of home gaming consoles, with the first to market being the Magnavox Odyssey.

Released in 1972, it had no CPU—just a collection of individual boards covered in diodes attached to a main circuit board. The packaging wowed with lots of accessories, but the reality was less impressive when it turned out you just moved a couple of squares behind a plastic overlay. That said, it did play a mean game of *Tennis. Computer Space* creators Nolan Bushnell and Ted Dabney started their own venture in 1972: Atari. At this time, Bushnell had seen a Magnavox Odyssey demo machine, which was running *Tennis* on a TV. History gets contentious here, but it's generally agreed that Atari decided to make a clone of *Tennis* for the arcades, dubbed *Pong.*

Tennis clones (now known as *Pong* clones) started popping up all over the place. However, it would only be so long before the public lost interest. It was clear that the home console needed a rethink, and Atari decided the single-game format needed to be discarded in favor of swappable games—so a microprocessor CPU would be needed.

Atari's bullish business tactics and financial backing would eventually see 1977's Atari Video Computer System—with its cheap MOS 6507 CPU—dominate the competition. It was later renamed the Atari 2600.

adventure
space invaders
combat
bowling
paddle
paddle
ATARI

The Atari VCS/2600 may have ruled the late '70s, but it was so low in memory, the game cartridges held extra RAM.

RUNNING SPACEWAR!

If you fancy a bash at *Spacewar!,* the easiest way is just to play it online—we especially like the version by Norbert Landsteiner at www.masswerk.at/spacewar. The screen surrounds and image blur are especially nice touches, and Norbert has gone into exceptional detail, making the experience as authentic as possible.

If you're determined to play it locally on your own machine, you're in luck if you own a Raspberry Pi. User Warpshock has written a tutorial for RetroPie users at https://bit.ly/2RtkTm6.

If you would like to run a PDP-1 emulator, your distro should have the simh package in its repositories. You can run the emulator by entering the following command:

```
$ pdp1
```

We tried to get *Spacewar!* running on our own machine through the PDP-1 emulator, but it's not as though it has an interface to import ROMs, like some kind of Nintendo emulator. It should be entirely possible to transfer *Spacewar!* into your session by remotely copying it, but after a day of chewing through manuals, we finally threw in the towel on that particular project. Please let us know how you get on.

Norbert Landsteiner's excellent online rendition of *Spacewar!*

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*HTTPS://EN.WIKIPEDIA.ORG/WIKI/SPACE_TRAVEL_(VIDEO_GAME)#LEGACY

BATTLE OF THE 8-BITS

In the 1980s, two home computers ruled the roost

TO SET THE SCENE for the rise of '80s micro-computers, we need to start with 1977's Apple II. It was available for the "cheap" price of $1,298 (around $5,370 in today's money), which bought you a 6502 CPU, 4K of RAM, and six colors—or 16 at very low resolution.

This was a great deal at the time, and was enough to seriously bloody IBM's nose. Although the hardware wouldn't change much in this period, costs had to come down drastically for home computing to really take off. Which they did—but the US and British approaches to this economic problem were vastly different.

The ZX Spectrum resulted from the battle of the 8-bit micro scene in early '80s Britain. Clive Sinclair would kick-start the British micro movement with the first home computer for under $200, 1980's groundbreaking ZX80. It had only 1K of RAM, a horrid keyboard, and the screen jumped with every keystroke. Nevertheless, it was enough to rouse the public's interest in home computing, and later resulted in the improved ZX81.

Meanwhile, a bitter rivalry was developing between Sinclair Research and its former employee, Chris Curry, of Acorn Computers. Things got genuinely ugly when the BBC wanted to commission a machine for its computer literacy project and TV series *The Computer Programme*. Every British manufacturer was putting in bids—including Sinclair—but only Acorn's design

SINCLAIR ZX SPECTRUM

SPECIFICATION
CPU: **Zilog Z80 @ 3.5MHz**
RAM: **16/48/128K**
GRAPHICS: **256x192 resolution, eight colors**
SOUND: **CPU-driven single-channel onboard speaker**
STORAGE: **Cassette and ZX Microdrive**
OS: **Sinclair BASIC**
RELEASED: **December 1981**
LAUNCH PRICE: **$220 16K, $350 48K**
PRODUCTION: **1982–1992**
WORLDWIDE SALES: **5 million**

The Speccy. It had an awful "dead flesh" keyboard, visually offensive color-clash, and truly disgusting audio, but it was cheap—real cheap. If you were a British kid in the '80s, this was the machine to fight for, the blue-collared hero that ushered in $4 gaming and earned Clive Sinclair a knighthood.

After losing the BBC contract to Acorn, Sinclair had to fight back, and did so by targeting the budget market, this time with a machine that could hold its own with videogames. Originally the "ZX82" (after the ZX80/81 predecessors), it was renamed to the ZX Spectrum to highlight its whopping eight-color palette. The use of a simple cassette deck for storage meant a whole new indie development scene developed, at which anyone could try their hand. Its list of games is utterly enormous, and it's impossible to do justice to the classics, but check out *Ant Attack, Head Over Heels, Skool Daze,* and *Manic Miner*—and it's obligatory to play a *Dizzy* game at least once.

As the '80s ploughed on, its real rival would be the Commodore 64. Although the Commodore was in most ways a better machine, the Spectrum still had some tricks up its sleeve, and its dirt-cheap price meant that in Britain it was in more grotty bedrooms of more spotty schoolboys (many of whom went on to be software developers). The Commodore looked and sounded better, but at least the Spectrum had a faster CPU and quicker tape drive.

COMMODORE 64

SPECIFICATION
CPU: **MOS Technology 6510 @ 1MHz**
RAM: **64K**
GRAPHICS: **320x200 resolution, 16 colors**
SOUND: **SID 6581 chip**
STORAGE: **Cassette, 5.25-inch floppy, and ROM cartridge**
OS: **Commodore KERNAL/Basic 2.0**
RELEASED: **August 1982**
LAUNCH PRICE: **$595**
PRODUCTION: **1982–1994**
WORLDWIDE SALES: **17 million**

Named after its 64K of RAM, the Commodore 64 was designed to be a great games machines from the outset, using custom chipsets to power functions separately from the CPU. The powerful VIC-II chip gave the Commodore 16 colors, hardware sprites, smooth scrolling, and a high resolution. The SID sound chip was developed by an actual musician, and wiped the floor with the competition—it's still used by musicians today—see the box opposite for more.

While many micros had features that were technically superior to the C64, Commodore's choice of hardware for the budget hit a sweet spot that punched well above its weight. One of the best choices was its use of hardware sprites; where other machines had visual tearing and color-clash, the C64's graphics were smooth and consistent.

Commodore's hardware gave users graphics and sound that were head and shoulders above the competition, quickly establishing the C64 as the gaming computer of choice. The Commodore would also become famous for its public domain "demo" scene, where programmers would show off their skills by pushing the machine to its limits, competing for the best sound and visuals.

CEO Jack Tramiel's aggressive price war (which brought the C64 down to near Speccy prices) also gave it a healthy business market. Why pay thousands for an IBM machine when you could spend a few hundred on something that plugs into a TV?

convinced the BBC. Eventually, an Acorn-built BBC Micro was gifted to every school in Britain, and Clive Sinclair needed to come back with something big.

In the US, home computing was going in more of a big-business direction, with players such as Apple, IBM, Atari, and Texas Instruments. Many machines were running on MOS Technology's 6502 processor, and Commodore's Jack Tramiel achieved a major coup by simply buying out MOS Technology. Now that Commodore owned the factory that produced everyone's chips, it was poised to wage an aggressive expansion campaign that would bludgeon the rest of the market, with the Commodore 64.

POST MORTEM

Both the Spectrum and C64 lived well past their use-by dates, and it was only the growing 16-bit market that brought them to an end. Although Sinclair itself folded in the mid-'80s, it was bought out by Amstrad, which kept the Spectrum line going with upgrades such as the 128K model.

By the late '80s, any pretense that these computers were designed for doing homework had long since disappeared, and both the Speccy and C64 were sold at bargain-basement prices as budget gaming machines. Indeed, Germans could buy a Commodore 64 at Aldi. The ubiquity of the Speccy's cheap games kept this machine going in the budget market right up until 1992, and more than 50 clones spread across the Soviet Union—some are still being produced in Russia today.

As for the Commodore, there were follow-ups, such as the Commodore 128 (a reasonable success), and failures like the ridiculous Commodore 64 Games system and the bizarre Commodore 65 prototype. But nothing touched the original. The software library was so vast that its popularity lasted well beyond the '80s, with a European resurgence in the early '90s (where it was more popular than the NES), and in Eastern Europe until the late '90s. Predictably, the hobbyist scene for both the Spectrum and the C64 is very strong, and people are still making games today, pushing the hardware to its absolute limits.

RAYDEN
99
SUB ZERO
ROUND

Soviet clones of the Spectrum gave us four highly unofficial ports of *Mortal Kombat* in the latter half of the '90s.

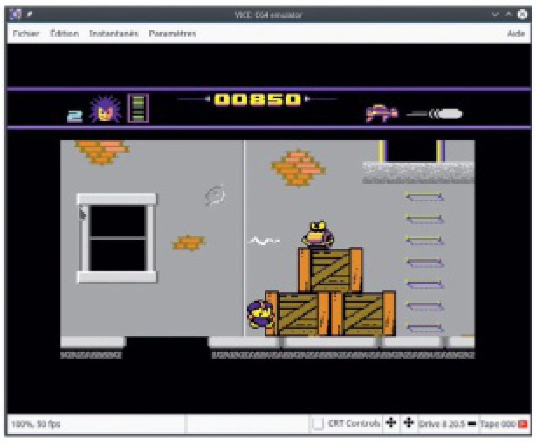
EMULATION

ZX SPECTRUM

The Fuse emulator should be in your repositories; install the fuse-emulator-gtk package, as it's much easier to run and configure. You'll need a system ROM to get started—our repositories had one, with spectrum-roms being the package. http://fuse-emulator.sourceforge.net

COMMODORE 64

The best emulator is VICE, though it's not the most user-friendly. Chances are it's in your repositories, but doesn't have a "KERNAL" for licensing reasons. First install your distro binaries, then grab the source tarball. Open a file browser (with superuser privileges) to "/usr/lib/vice," compare these files and folders with the data folder in the source tarball, and copy any that are missing. http://vice-emu.sourceforge.net



The C64 scene continued well past the '80s, with polished offerings like 1997's *Bleep Boy,* whose graphics look firmly 16-bit.

COMMODORE 64 MUSIC

Most 8-bit machines relied on the CPU for audio, making do with simple "bleep bloop" noises, but the Commodore was designed to have a strong, dedicated sound chip from the beginning—the SID 6581.

The SID (Sound Interface Device) was developed by a musician, Ensoniq's Robert Yannes. Distinctly unimpressed with the primitive existing computer audio, he designed a multi-channel audio chip that simply destroyed the competition.

Sporting three channels, each has an ADSR envelope generator and the ability to apply audio filters. Interestingly, a by-product of hardware imperfections resulted in effectively another channel—allowing for 4-bit digital samples—often used to synthesize speech.

The SID outlived the Commodore 64 and would become the basis for many pieces of pro music hardware, though since production has stopped, any remaining chips command a high price. The chip is still popular today, with its own underground scene. Any audiophiles out there will have seen software for C64 SID files in their package managers, and there are even live cover bands of famous C64 tunes. If you fancy hearing the SID for yourself, check out the online radio station at www.slayradio.org.

THE 16-BIT ERA: BRING THE MULTIMEDIA

A golden era of choice, rapid development, and modern capabilities

THE 16-BIT COMPUTERS would be dominated by one man and one CPU. The CPU was the Motorola 68000, known in the business as the 68K—a multimedia powerhouse whose potential had not yet been tapped. The man was head of Commodore, Jack Tramiel.

Tramiel was an aggressive man with even more aggressive business ideals—Commodore was sick of Jack, and Jack was sick of Commodore. Atari was old, bloated, and bleeding money, and parent company Warner wanted rid of it. Key Atari engineers wanted to make a new machine based on the 68K, but Atari wasn't interested, so they left to create their own company, Amiga. Tramiel also left Commodore to go his own way, and bought Atari's consumer division.

Tramiel now had an established brand under which to sell new products, bringing his own team of engineers with him from Commodore to work on the new 16-bit machine: the Atari ST. This left Commodore without engineers for its next-generation

ATARI ST

SPECIFICATION
CPU: **Motorola 68000 @ 8MHz**
RAM: **512K (up to 4MB)**
GRAPHICS: **320x200 with 16 out of 512 colors, 640x200 with 4 out of 512 colors, 640x400 monochrome**
SOUND: **Yamaha YM2149F three-voice squarewave plus one-voice white noise**
OS: **GEM, via Atari TOS**
STORAGE: **3.5-inch floppy, optional HDD**
RELEASED: **June 1985**
LAUNCH PRICE: **$800 (base model)**
PRODUCTION: **1985–1993**
WORLDWIDE SALES: **2.2 million**

Regarded by many as the first proper 16-bit computer, the ST was a powerhouse bargain for its time. Jack Tramiel wanted to make something that would walk over the Mac and IBM PC for a much lower price. Arriving a month before the Amiga, prices were around $500 cheaper than the upcoming Commodore Amiga 1000 equivalents.

For an operating system, Atari rejected Microsoft's unfinished version of Windows in favor of Digital Research's GEM (Graphical Environment Manager). GEM was only available for x86 processors at the time, but after porting it to Motorola's 68K, and combining it with the underlying DOS system, the results were dubbed TOS—"The Operating System." This was a genuinely pleasant environment, very similar to the Macintosh, and often dubbed the "Jackintosh" after the Atari boss.

TOS was a hit with consumers. The Atari had a high-res monochrome mode that was very popular with businesses, particularly when you could get an Atari with a printer and hard drive for less than the cost of an IBM printer alone. Furthermore, it could read MS-DOS floppies, and even emulate Mac software (and run it faster than a Mac).

The cheap sound chip was awful, but Atari made up for it by including MIDI ports—a stroke of genius. Plugged into external MIDI equipment, the ST truly shines, with better latency than a lot of pro equipment.

COMMODORE AMIGA (500)

SPECIFICATION
CPU: **Motorola 68000 @ 7.16MHz**
RAM: **512K (up to 8.5MB)**
GRAPHICS: **4,096 colors at 320x256, 16 colors 640x512**
SOUND: **Custom MOS Paula chip, 28KHz**
OS: **AmigaOS 1.2**
STORAGE: **3.5-inch floppy, optional hard disk**
RELEASED: **July 1985**
LAUNCH PRICE: **$1,300**
PRODUCTION: **1985–1996**
WORLDWIDE SALES: **4.85 million**

At first glance, it appears the ST had the Amiga licked for price and power, but look more closely, and the picture becomes very different. Both these machines use the 68K CPU, but the Amiga had a large color palette and a proper multitasking GUI.

More importantly, the Amiga was designed around multiple co-processors for handling audio, video, and memory access, thereby freeing up the CPU and outperforming the competition. Unlike the ST, the Amiga had a great sound chip, with advanced features that wouldn't be available on the PC for years.

While Atari had found an instant market with music composers, the Amiga had its own niche: video editing. With the right hardware, Amigas could "genlock" with video signals, matching their refresh rates, and enabling video overlays and easy effects. For a few grand, someone could get into professional video editing for less than a tenth of the cost of existing systems.

Modification was very popular, and it was common to fit Amigas with expansion boards with a second CPU, enabling Mac or PC functionality. It didn't take long for the Amiga to branch off into different, more advanced models, but it was the budget Amiga 500 that was the real hit. Released in 1987, the 500 was almost half the price of the original. Costs were cut by repackaging the bulky desktop case into micro form, new chipsets enabled simplified design, and lower RAM prices allowed for 512K of RAM.

computer. Amiga needed money and Commodore needed a new computer, so Commodore bought Amiga outright. Thus the stage was set for the next great computer rivalry.

POST MORTEM

Although the 16-bit Atari ST and Amiga put themselves in the same category as IBM's 286 line, they were more like the 32-bit 386 and 486 machines of the day. With software that was released on both IBM-compatibles and the 68K machines, it was more likely that the PC versions would be designed for a 386 or 486.

Interestingly, these computers would split largely into two markets: the IBM-compatibles for North America, and the 68K machines in Europe. It's tricky to find sales figures for the ST, but the Amiga only sold around 700,000 in the US, and around 75 percent of Atari's sales came from Europe. Most software titles are therefore European—France loved the ST, and the Amiga was king in Germany and Britain.

Over the years, Atari released better machines to rival the Amiga, and the Amiga continued to change and evolve over its life; full 32-bit models were popular in the '90s, and there was a failed attempt at the console market with the CD-32.

As the '90s progressed, IBM-compatibles were becoming cheaper, and neither company could compete. Commodore filed for bankruptcy in 1994. Atari made some 32-bit machines in the early '90s, but stopped making computers in 1993 in favor of the Jaguar console. This failed spectacularly, and ultimately sank the company at the time.

Believe it or not, you can still buy Amiga clones, and AmigaOS is still going, running on PowerPC architecture. There's also MorphOS, and AmiKIT will run an AmigaOS simulation over your existing desktop with a classic software collection Then there's AROS, an open-source AmigaOS that runs on modern hardware (such as the x86 and Pi) and the Amiga itself, if you can find one.

CREDIT: YOUTUBE, BOSE, HTTPS://YOUTU.BE/EFIZWVOTZ1M

When games came in proper big boxes, with manuals….

EMULATION

ATARI ST

If you just want to boot into an ST, Aranym basically simulates an ST wholesale. It was in our repositories, but needed a system ROM to start. Enter EmuTOS, an open-source TOS replacement that even works on a real Atari ST. Grab the EmuTOS tarball from http://emutos.sourceforge.net, and then copy the contents into Aranym's config folder in "~/.aranym." That should sort it.

Hatari is like most emulators (well optioned), rather than a straight simulation—you can find out more at https://hatari.tuxfamily.org. It's probably in your repositories, but will need its own TOS image as well. Once again, EmuTOS can provide that.

AMIGA

The most popular emulator is FS-UAE, which should be in your repository, but make sure you install the launcher package as well. If you're running without a custom system ROM, make sure you set the machine to emulate the Amiga 1200, as this will guarantee the best compatibility. https://fs-uae.net

The Atari ST's brilliant MIDI functions are used by big-name artists, such as Fatboy Slim.

DOSBOX

Used all over the world, DOSBox is a DOS emulator that runs everything and is available on a zillion platforms. It will undoubtedly be in your distro's repositories, and you won't need a BIOS file for it. However, it does take a few steps to get it going like a normal DOS machine.

We won't show you how to use DOS, but we will show you how to set up your C: drive. DOS used a simple file called autoexec.bat to run its startup commands, but DOSBox doesn't actually have this file, nor does it start with a C: drive. You need to edit its config file to emulate autoexec.bat and assign a C: drive.

For this demonstration, we'll assume you're putting all your files in a folder called "/dosbox" in your home directory—this folder will be the C: drive. If you enable hidden files in your file manager, the DOSBox configuration is in the hidden folder "~/.dosbox." Scroll to the bottom of the file, and find the section [autoexec], where you put in your lines to execute at startup. Add these two lines, and DOSBox will now start up with your C: drive ready to go:

```
mount c ~/dosbox
c:
```

HOW THE PLAYSTATION CHANGED EMULATORS

Modern console emulation had a drawn-out and painful birth, but it was all worth the effort

OUT OF ALL THE CONSOLES we could have covered, we chose the PlayStation because of its influence on emulator history. Initially, emulators for the PlayStation were buggy, unprofessional, and just too niche to worry Sony. However, two polished commercial titles would completely rock the boat and reshape history: bleem! and Connectix Virtual Game Station.

In the mid-to-late '90s, the Macintosh was starved of games, and emulators were becoming more popular. Connectix was a small company with a talent for virtualization, which was working on a PlayStation emulator for the Mac—Virtual Game Station (VGS). Having the PlayStation library would immediately expand Mac users' gaming options, and VGS could run PlayStation games at full speed on a relatively modest iMac G3.

Connectix tried to do the right thing by running it past Sony, hoping to license the BIOS and get some kind of endorsement. It put on a demonstration for Sony America's CEO, but this only angered Sony, which sent a cease and desist letter, and would not permit Connectix to use the PlayStation's BIOS code. Having already come this far, Connectix started reverse-engineering Sony's BIOS to make its own compatible replacement, without any Sony source code.

Connectix set up a stand at that year's MacWorld Expo and, excited by the new gaming prospects for the Mac, Steve Jobs spoke enthusiastically about the product in his keynote speech. Sony happened to be at the Mac conference as well, and after a visit to the company's booth, it served a lawsuit on Connectix.

Connectix initially lost this battle, but appealed against the decision. Amazingly, on 10 February 2000, a court ruling deemed that its reverse-engineering was necessary to gain access to unprotected functional elements within the system.

Given that Connectix hadn't used any of Sony's code in its BIOS, it was deemed that its work constituted fair use. Sony would go on to buy out Connectix and kill the product, but the Sony versus Connectix court ruling opened the floodgates. This was a landmark ruling for emulation as a whole, legitimizing both emulation and reverse-engineering.

Connectix may have opened the market, but it was bleem! that really brought emulation into the mainstream. Released in 1999, bleem! was considered one of the best emulators of all time. Not only did it have surprisingly modest system requirements, it even had 3D acceleration, which could enhance the visuals of PlayStation titles.

Its developers were confident that they wouldn't face legal action from Sony. After all, bleem! was created legally, being entirely reverse-engineered, plus it ran games from the original retail CDs, and therefore didn't promote piracy. However, the product's CD cover may not have gone down well with Sony at all, boasting "Higher Resolution—More Detail—Richer Color!" Sony gave it both barrels, with a series of lawsuits. No one expected the devs of bleem! to fight back, but they did—and to everyone's surprise, they won. Repeatedly. Bleem! became hugely popular, and by the end of the decade, pretty much everyone had a copy—

SEGA SATURN (1994)

Unlike the PlayStation, the Saturn is a deeply complex machine, with a dual-CPU setup, and eight processors overall. Initial sales were good in Japan, but Sega ruined its launch in the West, and never really recovered from it. Unfortunately, the Saturn was not well documented and is considered tricky to program, so most games never harnessed the performance the system could have given.

Despite this, Saturn games are aging nicely, and fetch top-dollar on the second-hand market. The Saturn was a beautiful machine crippled by company mismanagement, but that makes the Saturn history's interesting underdog, with many gaming gems westerners have never heard of.

Unfortunately, all those processors make the Saturn very difficult to emulate, and years later, things are still quite patchy. The favorite emulator is still Mednafen, but it's very system-intensive, and can be difficult to get working.

Yabause has seen a lot of development lately, and is catching up with Mednafen—it's also much lighter and faster. It was in our repository with both GTK and Qt GUI front ends, and didn't require any further steps, such as a BIOS. If neither solution works for you, the Yabause core can be used under RetroArch: https://yabause.org.

Loved by some—but not enough.

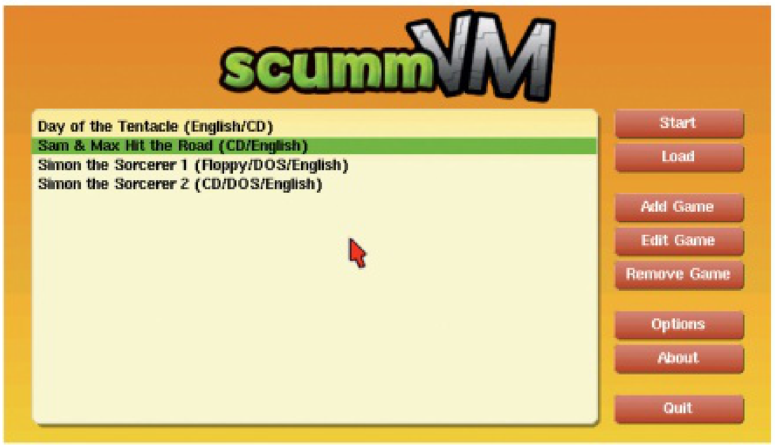
SCUMMVM & LEGAL ROMS

ScummVM (Script Creation Utility for Maniac Mansion Virtual Machine) is an ambitious reverse-engineered project that runs the point-and-click adventure games popular in the '80s and '90s. Particular attention is given to LucasArts games, and by doing away with the need for the original game executable, ScummVM is very multi-platform. For those so inclined, ScummVM enables you to upscale and smooth out the original graphics, and audio power users can tweak the sound and MIDI systems.

LEGAL ROMS

We've mentioned the illegality of ROM downloads numerous times, but there are legitimate avenues. Machines like the Commodore 64 and Amiga had thriving demo scenes with tape-trading and magazine coverdiscs, and consoles like the PlayStation and Dreamcast had magazine cover CDs. Public archives are available online to preserve much of this data.

Then there's homebrew gaming, where hobbyists publish unofficial titles for other enthusiasts, and traditionally this software has been public domain. However, the easiest form comes from game companies themselves, which are using technologies such as DOSBox and ScummVM to sell their old games on stores like Steam and GOG. Even if there's no Linux version for what you're chasing, there's still a very good chance it will work under Wine or Proton.



Day of the Tentacle (English/CD)
Sam & Max Hit the Road (CD/English)
Simon the Sorcerer 1 (Floppy/DOS/English)
Simon the Sorcerer 2 (CD/DOS/English)

Nearly all of LucasArts' adventures are stone-cold classics. Play them with ScummVM.

it was fun showing console peasants *Metal Gear Solid* in high resolution (and "richer color").

Ultimately, bleem! sales dried up, and Sony's constant litigation wore down both Connectix and bleem!, but these companies set a legal precedent, and made emulation mainstream. Nowadays, major game companies emulate their older games on newer systems, even Sony itself (to a degree).

PLAYSTATION EMULATION TODAY

The PlayStation hardware was relatively simple compared to its rivals, and there have been numerous emulators over the years. No one talks about it being a mysterious puzzle to crack, but there is one challenge that continues to plague PlayStation emulators today—the BIOS. While there are open-source replacements, compatibility isn't brilliant, and most guides suggest just using the proprietary Sony BIOS, despite the legal issues.

Starting with the purest open-source Linux option, your best bet for now is PCSX. This should be in your repository, and comes with its own BIOS replacement. However, if you get a real BIOS (we're not going to tell you where from), copy the file to "~/.pcsx/bios/" and select it in the configuration. If games crash immediately, open the "Configuration" menu, and try changing the driver from OpenGL to XV under "Plugins and BIOS."

We had mixed results with PCSX, and it didn't work on all our machines. Though it pains us to say it, the closed-source ePSXe worked much better. Although it can make use of a BIOS replacement, the official BIOS is still recommended, and save states apparently won't work if you switch between BIOSes (though this may have changed in recent years). Its website at www.epsxe.com provides a tarball with a binary pre-compiled and almost ready to go, but you need to make it executable. Right-click the file, choose "Properties," and somewhere in your file manager should be the option to change file permissions, where you can flag it as executable. You should be able to just click the file and have it run now, though you'll want to set up basics such as controls and video modes. The defaults aren't great, and ePSXe probably won't automatically set up your gamepad (at least, it didn't for us).

RetroArch and Mednafen are two other alternatives, though both require a BIOS and a certain amount of configuration. RetroArch needs quite a few steps to get PlayStation games working, but there are plenty of guides online to get you going. Mednafen kept giving us some very strange errors, and eventually we headed back to ePSXe in frustration.

For those willing to work past the initial barriers, the PlayStation library will be worth it. Sony was an upstart in the console market, but trounced all its competitors, the PlayStation becoming the biggest console of the '90s. From *Metal Gear Solid* to *Gran Turismo* to the *Final Fantasy* games, the number of classics is just far too long to list.

PlayStation magazines also had coverdiscs filled with demos—something that used to be almost the sole domain of PCs. This fostered an underground coding scene in ways that companies like Nintendo never could, thus the PlayStation library is colossal.

The work of Connectix and bleem! may have been lost over time, but their precedent is not. Open-source BIOS replacements are becoming increasingly popular, and emulators like DeSmuME for the Nintendo DS and Citra for the 3DS just run immediately.

Before we go, there is one final twist to this saga. The recent PlayStation Classic console, officially licensed by Sony, itself uses an emulator to play old ROMs: ReARMed, an ARM port of PCSX. Which is open source. But we don't want to advertise that too loudly, because reviews haven't been great—most of us can set up a better default configuration than Sony!

GETTY IMAGES

CLOUD GAMING: DREAM OR NIGHTMARE?

As Google announces the Stadia, *Christian Guyton* investigates the past and future of cloud gaming

IT'S A FUNNY THING, streaming. For movies and TV, it's no surprise that it's taken off; services such as Netflix and Amazon Prime Video offer unlimited on-screen entertainment at subscription premiums, demanding only 5Mb/s to deliver HD-quality movies to our televisions, office computers, and cell phones. Music is even less demanding—just ask Spotify to quote you its crisp $1.5 billion revenue from the last quarter of 2018. But gaming? That's a whole different ballpark. In fact, we're not even sure if it's the same sport.

Issues that make zero difference to the streaming of movies or music become huge complications when games enter the fray. Frame rate? Latency? Load times? All big concerns. Nobody cares (or even notices, really) if there's two-tenths of a second between pressing the pause button on your Netflix Original show and the action stopping, but such a delay could be the difference between victory and crushing defeat in a high-stakes match in *Call of Duty*. Games—even single-player ones—chew up bandwidth like nothing else when played via streaming, too; 5Mb/s isn't even close to enough for anything remotely demanding.

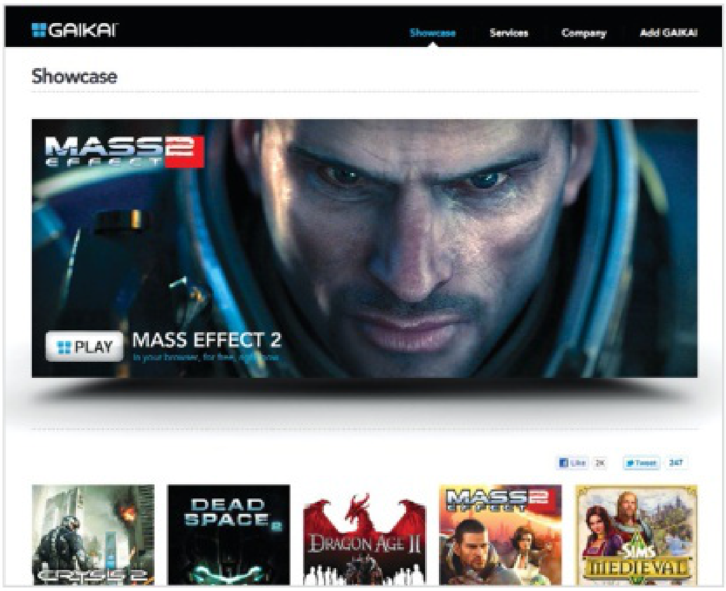
Many have tried and failed to deliver the perhaps-mythical "Netflix for games" often discussed by developers and journalists alike, with each doomed attempt leading to a slew of articles touting streaming-based gaming services as a dead medium. It's a tired cycle that has been struggling onward since the early 2000s, each new attempt drawing huge excitement before crashing and burning to a painful halt.

Enter Google, as it always does, with its own hot take on the latest fad. Announced at the 2019 Game Developers Conference in San Francisco, the Google Stadia promises to be the Next Big Thing in the game-streaming world. With multiplatform support, 4K and 60fps capability, and an evolving cloud-based infrastructure, Stadia is perhaps the most ambitious project of this type to date—but will it succeed? Only time will tell, but for now, we can take a deeper look at the history of streaming-based gaming platforms, and what directions they might take in the future.

STADIA IS FAR FROM the first of its kind. The notion of streaming-based gaming platforms has been around for close to two decades, ever since YouTube exploded in popularity in the mid-noughties. To be able to play games without ever having to purchase and download them does sound attractive, but the execution has always been flawed. The theoreticals were first demonstrated by G-cluster at the 2000 Electronics Entertainment Expo, with Crytek investigating the possibilities a few years later before shelving the idea due to concerns about consumer Internet speeds. The first big hitter to take on the challenge of a streaming-only game platform was OnLive, a Californian company that specialized in cloud computing. Its flagship product was its proprietary cloud gaming service of the same name, first announced at GDC 2009, exactly one decade before Google decided to take a shot at the crown at the same event.

OnLive managed to gather some real traction in 2011, capable of operating on multiple versions of Windows and MacOS X, as well as Android smartphones, tablets, and even some smart TVs. This was followed by the announcement of its own game system, referred to as the OnLive MicroConsole TV Adapter. Unlike its name, the console was a compact affair with a wireless controller, capable of turning any TV into a gaming screen with little more than an HDMI cable and an Ethernet connection.

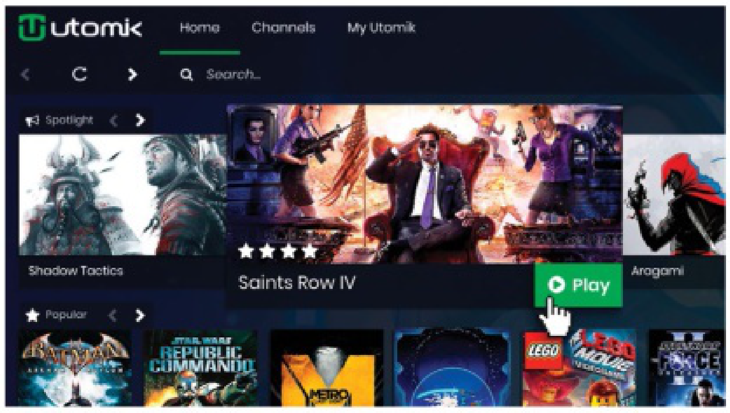
Sadly, all was not well. OnLive folded in 2012, resulting in numerous lay-offs and sale of assets—though the story wasn't quite over. A new company was formed—also called OnLive—running a smaller team and shifting focus by 2014 to a new service called CloudLift, which used cloud-based storage to allow gamers to switch between devices while playing the same game. A year later, though, in came Sony, buying up all of OnLive's assets, and announcing that it would be shutting down all of its services. Why was Sony so eager to snap it up? We'll get to that.



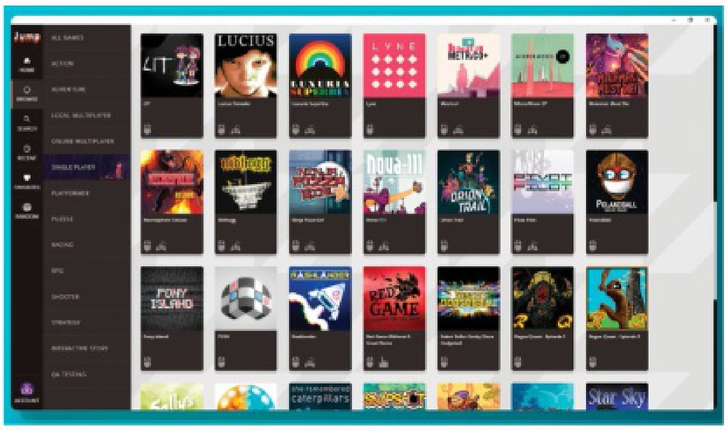
Gaikai's service didn't survive acquisition by Sony.

PlayStation Now
Game Streaming Subscription

PS Now contains games from three console generations.



Utomik still requires games to be installed on your PC.



Jump is dedicated to supporting indie developers.

SONY STREAMING

Around the same time, another Californian company named Gaikai was doing its best to perfect the tech. Early demos were impressive; games could be embedded on websites using Adobe Flash Player, and it demonstrated triple-A games such as *Modern Warfare* running effectively on tablets and PCs with a sufficiently fast Internet connection. Gaikai enjoyed some success in 2011 and 2012, running a service model called the Ad Network, which enabled websites to stream demos of games and receive a portion of marketing revenue. It also ran an Open Platform model, enabling the streaming of full games to a variety of devices.

Then, later in 2012, in swooped Sony, snapping up Gaikai for a hefty $380 million. Gaikai's tech was put to good use at Sony, forming the basis for the PlayStation 4's Remote Play function. Remote Play had actually been around for a while at this point, available on the PlayStation 3, but it had to be integrated into games on a software level by developers. Very few releases had this function, because developers weren't willing to devote resources to supporting Sony's ailing PSP and PS Vita sales—there were only 14 physical releases that supported the Remote Play service across the PS3's entire lifespan.

The PS4, on the other hand, had Remote Play built into the hardware. With Sony taking the leap and installing the functionality on every PS4, the option of dipping out for game devs was gone: If you wanted your game on Sony's platform, it had to be compatible. Lo and behold, a home console that could stream to your handheld anywhere with a decent Internet connection. This Gaikai-powered tech was relatively effective—latency still meant that high-intensity online shooters were out of the picture, but the principles of the software were sound. The main stumbling block

> "That barrier isn't something you can punch through with capital" **PATRICK WEEKERS, UTOMIK GROWTH DIRECTOR**

Remote Play wasn't enough to salvage the PS Vita's sales.

was the requirement of a PS Vita, but in 2014, the software became available for Sony smartphones and tablets, too, followed by Windows and MacOS.

SCALED DOWN

This technology works as a microcosm of conventional cloud gaming services like OnLive and Stadia. In OnLive's model, games were run on a large remote server base, which could theoretically run any game, delivering high frame rates and graphical quality. Remote Play replaced the servers with the consumer's own PS4, which would simply run the games as normal while streaming video feedback one way and controller input the other, enabling near-seamless switching between a mobile device and the usual TV setup. Remote Play is still available, but failed to make a lasting impact. The next step, then, was for Sony to deliver its own PlayStation-branded cloud gaming service: In 2014, the world said hello to PS Now.

PS Now works much like OnLive did: Using a PS4 (and later, PCs), players can choose from a library of over 700 PlayStation 2, 3, and 4 games to stream from Sony data centers direct to their screens. Latency issues still plague the service, but it has performed well enough for Sony to keep rolling it out to new countries throughout 2019. OnLive's acquisition by Sony in 2015 saw its tech put to use in improving the PS Now service.

Sony appears committed to making the subscription-based service work, and the library is ever-expanding—although, tellingly, last year saw Sony announcing that some games would be available for full download on to consumers' PS4. This eliminated input latency issues caused by streaming, but removed the instant-play benefits of fully streamed games. Still, PS Now continues to expand, with new games being added every month.

LIKE AND SUBSCRIBE

Subscription-based gaming platforms that allow downloading local copies of games are nothing new, either. PC gaming service Utomik acts as a middle ground between traditional user-ownership and fully cloud-based gaming. Rather than streaming from a server, Utomik's games are partially downloaded to the PC, with nifty technology that adapts to the user's Internet speed—with the company promising zero lag and buffering issues, regardless of your bandwidth. In our tests, Utomik proved speedier and cheaper than normal purchased downloads, but not quite as instantaneous as cloud gaming. It works—games are ready to play within seconds, with no latency issues from data streaming, though the need for local hardware remains.

Utomik's growth director, Patrick Weekers, had his own take on the Stadia announcement, remarking that "it proves public perception of subscription gaming (and access versus ownership) has evolved, which has caused big tech companies to scrabble for a share of the market." Weekers wasn't overly impressed with Stadia, though, calling it "just another cloud streaming announcement," and commenting that "the technology for a fully

CONSOLATION PRIZE

Console gaming numbers have always fluctuated up and down, but home consoles do seem to be steadily trending downward as the costs associated with them increase. The peak of console gaming occurred around the turn of the millennium, with Sony's PlayStation 2 smashing every record to sell a whopping 150 million units. By comparison, the PlayStation 4 has only sold around 95 million units in the five-plus years since its release, while the Xbox One barely managed a measly 39 million. Nintendo dominated the handheld console market, with the Nintendo DS managing to match PS2-tier sales figures, and the Game Boy and Game Boy Color before it both topping 100 million units sold.

The rise of gaming-ready smartphones has hammered the handheld console market, though. The strange home-handheld hybrid Nintendo Switch has seen a modicum of success, but why bring a bulky handheld console with you to play *Fortnite* on your lunch break when you could just do it on the phone that's always in your pocket? Home console sales aren't exactly decreasing—they vary significantly, spiking around Christmas time every year—but they're not rising either. Sales rates held mostly steady last year for all three major home consoles on offer right now (PS4, Xbox One, and Switch).

Elsewhere, Valve reported an $800 million rise in profits from Steam sales revenue in 2017, while digital sales of home console games continue to struggle—indicating, perhaps, that serious gamers are slowly but surely making the switch to PC gaming. Streaming solutions do offer a potentially strong option for casual gamers; a cheaper barrier to entry, less required hardware, and no lengthy downloads or updates mean that services like Stadia could provide a more accessible way to play games—particularly if they expand on to smartphones.

Sony has never reached greater heights than the PlayStation 2's staggering sales figures.

streamed solution just isn't there yet. 5G networks, for example, are still being tested, meaning most consumers will not be able to use this technology any time soon, let alone on all devices at any time. That barrier isn't something you can punch through with capital." We're willing to bet that Google will give it a shot, though—if anyone has the bucks, it does.

Weekers isn't the only one unconvinced by Stadia. Another successful service of this sort is Jump, an indie-focused platform with a subscription fee of just $5 a month. With a curated library of over 100 indie titles, Jump recognized the hurdles to cloud-based gaming early on. Its HyperJump progressive download technology downloads games in small segments, then removes them once they're done being used, giving the impression of a fully installed game. This tech adapts to the user, keeping data from popular games cached to minimize load times. Games can even be played in a browser—when we reached out to it, Jump was keen to emphasize the advancements in modern browser-based gaming, from speedy load times to shareable links to games and embedded demos. We gave Jump a go, and found that indie games could run flawlessly even on an iMac, in Chrome, with a dozen other tabs open. Somehow our computer didn't catch fire.

Jump CEO Anthony Palma voiced concerns about pricing and latency, commenting that "latency is inescapable in streaming until 5G and fiber are in every household," adding "I think streaming has potential to be a gamer's console replacement... in 10 years." Jump views subscription gaming as a "complement rather than a replacement" for user-ownership. Palma likened it to movies moving from the theater to subscription services; both are key revenue streams for the movie industry.

STADIUM LOVE

So, Google Stadia. It's a cool name, we'll give it that. Better than the achingly dull-titled Project Stream, which Google ran last year as a then-suspected, now-confirmed beta test for Stadia. Project Stream (ugh) saw recent releases such as *Assassin's Creed: Odyssey* running at 30fps and 1080p in ordinary browsers. The lower frame rate and resolution gave Project Stream space to mask latency issues, and *Odyssey* isn't a game that demands frame-perfect button inputs. Stadia, though, promises up to 4K 60fps gameplay with minimal latency. It's a bold claim, and one that comes with the caveat of an Ethernet connection with high Internet speed.

Stadia's fundamental systems work using familiar hardware; input is streamed directly to a Google server running your game of choice in one of its many data centers, which feeds back live video of the game to your device. AMD was pleased to announce its partnership with Google, its top-end data center GPUs powering Stadia's actual gameplay—although Google has been tight-lipped about the specifics, it's been revealed that the CPUs are actually Intel-powered. Stadia is promised to run on an assortment of desktops, laptops, smartphones, and tablets, although any mention of iOS was conspicuous by its absence in project leader Phil Harrison's presentation at GDC 2019. Predictably, Apple revealed

Behemoths beware: the Stadia controller's central buttons are very tiny.

GAME ON

Playing games over a stream is a tricky business, not least become some games stream better than others. One of the key benefits of cloud gaming is the fact that it enables games to be played at a high level of graphical quality (thanks to powerful data center GPUs) on even the most basic devices. In theory, if you've got a screen and an Internet connection, you should be able to instantly play games on ultra graphical settings. In practice, not every service has managed to deliver this. We've been banging on about latency a lot in this article, we know, but the fact is that it tends to tank a lot of fast-paced games. With that in mind, what are some good games to play over cloud gaming platforms?

Turn-based strategy and RPG games are excellent, particularly ones that are less visually demanding. Indie gem *Into The Breach* is an ideal example of a game that runs perfectly when streamed, regardless of connection speed. Even real-time strategy titles such as *Total War* function reasonably well. *Doom Eternal* has been touted as the first triple-A launch title for Stadia, which is exciting—if it runs well. Demos we've seen so far have been visually appealing, but input lag means the game can stutter badly, leading to gameplay issues and an overabundance of motion blur.

The games that really suffer when run on cloud-based platforms are online multiplayer titles. Want to stream *Apex Legends* or *Call of Duty?* Well, your input needs to go from the controller to your console or computer, then to the data center where the game is hosted, then to the game's own servers, then all the way back again. Latency will shatter any notion of quick reaction times. *Rocket League?* Yeah, good luck with that.

***Doom Eternal* on Stadia felt a little rough around the edges when demoed at GDC.**

Cloud gaming solutions use beefy data centers to run games.

Online shooters struggle the most on cloud gaming platforms.

its own competing service—Apple Arcade—not long after. Details are thin on the ground, but Arcade seems to have more of a focus on mobile gaming than Stadia.

What sets Stadia apart is its controller. The Stadia gamepad should be familiar to anyone who's handled any home console controller, connecting directly to your home Wi-Fi to cut out some of the latency issues that come with traditional controllers, which need to send input data through a local device first. The controller also comes with an integrated mic, plus buttons for Google Assistant and video capture. The controller doesn't have a catchy, Google-themed name yet, but we wouldn't be surprised—especially as it's the only piece of new hardware you need to buy to get playing. StadPad? Google Croissant? You can have those for free, Google.

UNCERTAIN FUTURE

Stadia is about nine months away from commercial release, but there seems to be an incredible number of unknowns around it. Streaming-based gaming services are not, in broad terms, aimed at PC gamers. Console gamers are more likely to benefit; home consoles are expensive, borderline impossible to upgrade, and most now come with their own subscription-based services for online play. Games themselves, too, are becoming costlier, particularly for current-gen consoles. Streaming solutions like Stadia could banish all of these expenses, but they come with their own costs. An Internet connection capable of supporting the service results in a price tag that isn't exactly small.

Will Google offset the prices with ads? Will there be a subscription service—and if so, will there be free and premium versions? How much will the controller cost? There are so many uncertain variables surrounding the Stadia, it's difficult to gauge whether it will soar higher than any platform before it, or crash out OnLive-style. The phrase "Netflix of games" is bandied around a lot, but is that really what gamers want? "YouTube of games" might be more appropriate; the idea of a free cloud gaming service with an available premium membership

CLOUD AND PROUD

A quick Google search for "failed game streaming services" rather damningly places OnLive at the top of the results list. It wasn't the only one to fall in the face of traditional downloads and physical copies, though. Gaikai's tech might have gone on to form a powerful baseline for PlayStation Now, but its original service failed to gain much momentum. Elsewhere, Square Enix's ill-fated effort Shinra lasted less than two years before it admitted defeat and shut it down, resulting in a loss of more than $16 million. Others simply vanished into the ether. If you've heard of InstantAction or GameFly, congratulations—you've been paying more attention than most.

GeForce Now, Nvidia's attempt at a cloud gaming platform, has been in an open beta state for months now. It allows users access to a server-hosted Windows environment running powerful GeForce graphics, where they can install and play games they already own from digital suppliers such as Steam or Origin. While nifty, it doesn't push the boundaries of what cloud gaming is capable of, and seeing its competitor AMD cozying up with Google for Stadia must be making a few Nvidia execs nervous.

One platform that has seen some real success is Shadow—a service comparable to GeForce Now that sees users connecting to a dedicated machine in one of Shadow's data centers, then using that machine to play games they already own in up to 4K 60fps, with multiplatform support available. Shadow has received acclaim from gamers (even a professional *CounterStrike: Global Offensive* team) regarding the quality of the service, but it demands 15Mb/s or faster Internet, and comes with an eye-watering $35 a month price tag—on top of the cost of the games. And lastly, no, Netflix doesn't count, no matter how much you enjoyed *Black Mirror: Bandersnatch.*

Shadow has its own hardware, namely the Shadow Ghost.

sounds attractive, and the potential ad revenue for Google is massive.

Internet speed requirements are a huge concern for would-be promoters of the Stadia, too. Google recommends a minimum of 25Mb/s—more than twice the average Internet speed in the US, and five times Sony's recommended speed for PlayStation Now. Some games are sure to devour bandwidth, and for users with limited data plans, Stadia could prove disastrous. Its performance on low-end routers and broadband packages remains to be seen, but we can't imagine it's good. Even on the Moscone Center's presumably industrial-standard Internet at GDC, demos showed slowdown and input latency.

HEAD IN THE GAME

And what of the games? *Doom Eternal* is a big-name title lined up for Stadia's launch, but we've seen little else—just *Assassin's Creed: Odyssey* (feels like it's everywhere right now). *Odyssey* looks beautiful, making it ideal for hardware demos, and it's no surprise it was the star of the show at the Stadia reveal; Ubisoft CEO Yves Guillemot is a big proponent of cloud-based gaming. In an interview with *Variety* last year, he stated that he expected to see "less and less hardware" in the future of gaming, claiming that "there will be one more console generation and then after that, we will be streaming, all of us."

Play one of the world's biggest blockbuster titles from the cloud.

***Assassin's Creed: Odyssey* does look beautiful running on Stadia.**

AMD promises a "robust" suite of tools for developers to optimize their games, and Stadia is interestingly mostly running off a heavily modified Linux variant. Ogi Brkic, general manager of AMD's data center GPU business unit, stated recently that AMD was "delighted to work with Google" on Stadia, promising "the reliability and no-compromises performance they (gamers) expect." Google and any developers working on Stadia projects will be able to use the open-source Linux drivers to more closely examine the code at play. It's certainly promising, but there's no way of knowing whether devs will take to it. Games will require changes in code design to run effectively on Stadia, and it could be that developers decide that it isn't worth the hassle. Stadia is more likely to unsettle the casual end of console gaming than hardcore PC gamers, but tackling the giants that are Sony, Microsoft, and Nintendo on their home turf won't be easy.

Whether Stadia will also support downloading local copies of games for improved performance—like Utomik, or Xbox's Game Pass—remains to be seen as well. What becomes of personal ownership when a platform only offers access to games on a subscription basis? Subscriptions are becoming less popular in the gaming world; a decade ago, *World of Warcraft* boasted seven-figure member counts, but those numbers have

techradar.

been trending steadily downward, while modern free-to-play games such as *Fortnite* operate a season pass system rather than premium membership subscriptions. It's easy to argue that fully subscription-driven games will never overtake the simple pleasure of buying a game once and owning it forever. That said, many were skeptical of Netflix when it emerged, and now DVD retailers are being crippled by the video-streaming giant.

So, is streaming-based gaming the way of the future? We don't really think so, but we're ready to be proven wrong. It feels as though we're stuck in a loop; this streaming technology keeps coming around, and each time the industry arrives at the same conclusion: It's a nice idea, but typical Internet connection quality isn't enough to support it. Stadia is flashy, and Google undeniably has the power to throw staggering amounts of money at it, but if it won't run on your average household broadband, there's no way it can take off. But hey—it's early days. Stadia is set to launch at the end of 2019, and a lot could change in that time. ⏻

STREAM IT YOURSELF

Much like PlayStation's Remote Play, there are other ways to stream games yourself, without the aid of a hulking data center. Kids hogging the TV? Xbox One enables you to stream games to any Window 10 PC connected on the same network, using the computer's monitor as a second screen, and connecting a standard Xbox controller. Because the game is effectively played in situ on the console, players can return directly to the big screen once the living room has been vacated.

Steam users have this option, too, albeit in reverse; in November 2015, Valve launched Steam Link, which enabled anyone to stream their Steam library from their gaming PC to their smart TV or mobile device, over a local connection. Initially, Valve sold a piece of hardware that supported Steam Link—a black box reminiscent of the OnLive console—but it was discontinued following the rise of smart TVs, which could support Link via an app. For the smart-TV-less, it's still possible to pick up a Link unit on Amazon, or use a Raspberry Pi to replace it—Valve's software is eminently compatible with the single-board computer. Just don't bother getting a Steam controller for it.

Another option for home streaming is Apple's AirPlay. Apple TV supports second-screen functionality for other Apple hardware, enabling a spot of couch gaming. Apple's tech isn't exactly ideal for gaming, to be fair, but it's good for a few games of *Fortnite* on the big screen without needing to splash out for a console or gaming PC (if you're a Mac fiend). Google Chromecast also enables your TV to display a live stream from your PC, but in practice this tends to be poor for gaming— sorry Google fans, you'll need to wait for Stadia.

Steam Link is great—just avoid the Steam controller.

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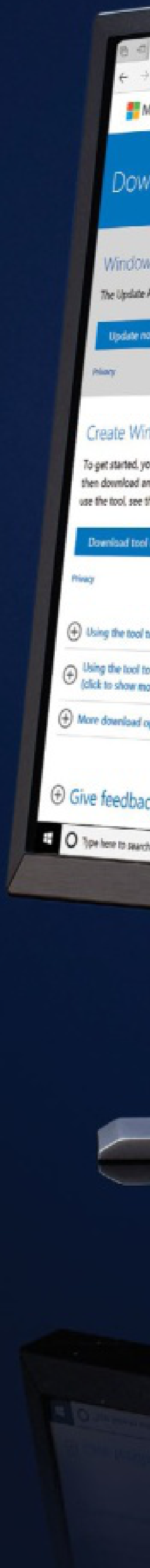
CREATE A CUSTOM WINDOWS INSTALLER

Cut down or bulked up; *Alex Cox* helps you to have the Windows you need



WINDOWS AND BLOAT. Two words that, however much you might feel like Windows 10 has become a svelte and lithe OS, go together like peanut butter and jelly. Preparing a new PC usually means a new installation of Windows, and what follows—at least if you're anything like us—is a painstaking pruning of autorunning applications, a violent excision of useless Metro programs, and the installation of all the stuff that actually makes Windows worth using.

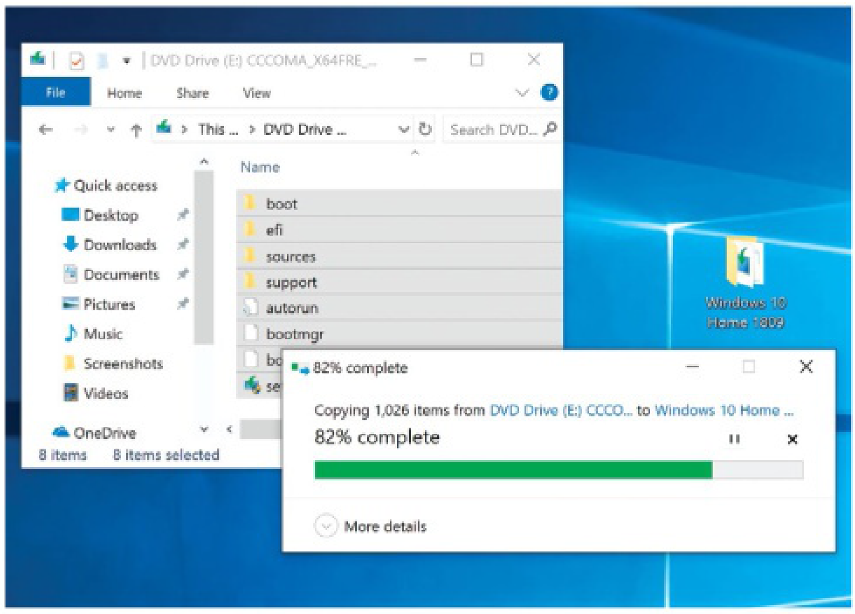
Now, we've looked at trimming Windows to shape, and scraping your disk clean of accrued files, and even silently installing a whole cache of favorite apps in the past. That's not quite what we're doing here: Arguably, the most efficient way to ensure a quick and painless Windows install is to customize the Windows installer itself.

Cooking up your own ISO means cutting out some chaff before it even reaches your boot drive, and integrating new components into the Windows installer (or at least including those installers on there, so you don't need to manually download them later). Note that while this is, legally, perfectly acceptable, it's generally more of an enterprise process, and carries no guarantees with it. You also (obviously) need a unique Windows key, of the correct version, for every machine to which you apply your customized ISO.

This isn't a walk in the park, nor is it pretty. Indeed, Microsoft's own primary ISO hacking tool is a command-line affair, and the vast majority of its front ends are GUI as GU-why. There are, thankfully, prettier options, and although perennial ISO chopper NTlite has heavily restricted what's available to non-paid users in recent years, you may find that the free version offers enough of a taste to get you salivating for more. The kind of Windows ISO you produce is really going to be up to what you're looking to achieve—while we could tell you exactly what to remove or what to tack on, and we'll certainly give you some direction, your customized and excised Windows is yours to sculpt for yourself.

Download Windows 10 Disc Image (ISO File)
Microsoft | Software Download
Select edition
AGON

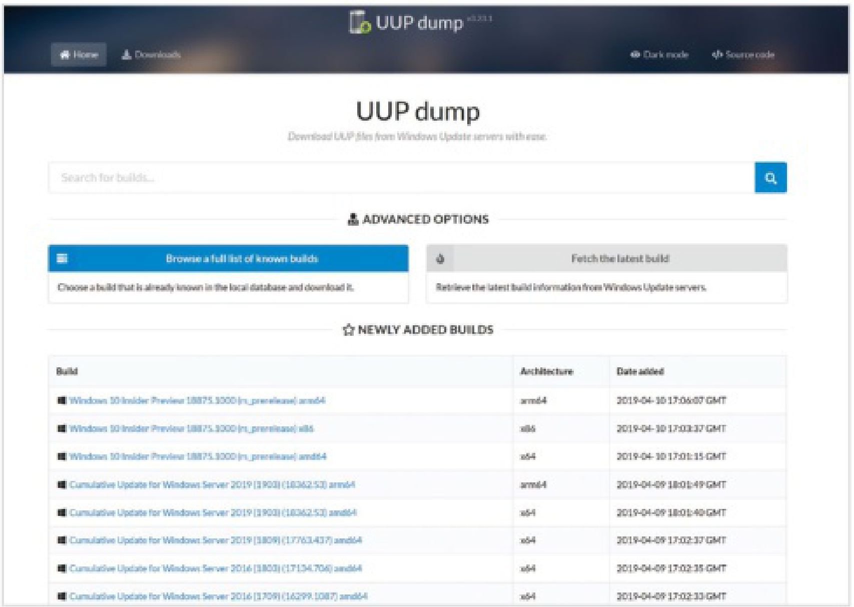
Same page, different browser user agent settings. Sometimes lying online is a good thing.



Copying 1,026 items from DVD Drive (E:) CCCO... to Windows 10 Home ...

82% complete

You need to work on the Windows installer files from a folder.



Download UUP files from Windows Update servers with ease.

Choose a build that is already known in the local database and download it.

Retrieve the latest build information from Windows Update servers.

Build	Architecture	Date added
Windows 10 Insider Preview 18875.1000 (rs_prerelease) arm64	arm64	2019-04-10 17:06:07 GMT
Windows 10 Insider Preview 18875.1000 (rs_prerelease) x86	x86	2019-04-10 17:03:37 GMT
Windows 10 Insider Preview 18875.1000 (rs_prerelease) amd64	x64	2019-04-10 17:01:15 GMT
Cumulative Update for Windows Server 2019 (1903) (18362.53) arm64	arm64	2019-04-09 18:01:49 GMT
Cumulative Update for Windows Server 2019 (1903) (18362.53) amd64	x64	2019-04-09 18:01:40 GMT
Cumulative Update for Windows Server 2019 (1809) (17763.437) amd64	x64	2019-04-09 17:02:37 GMT
Cumulative Update for Windows Server 2016 (1803) (17134.706) amd64	x64	2019-04-09 17:02:35 GMT
Cumulative Update for Windows Server 2016 (1709) (16299.1087) amd64	x64	2019-04-09 17:02:33 GMT

We wouldn't blame you if you were a bit baffled by UUP Dump.

If you're putting together a Windows 10 ISO, it figures that your first step should be getting hold of a Windows 10 ISO. Problem is, if you're already running Windows, Microsoft doesn't make this easy: Head to www.microsoft.com/en-gb/software-download/windows10, and you're redirected to run through the company's Media Creation Tool, rather than just being offered up the goods. But using another OS, such as MacOS or something Linux-based, gets you direct access to the ISO. The key is to have your browser lie to the website by spoofing its user agent. In Chrome, this means hitting Ctrl-Shift-I to open developer tools, clicking the three dot icon, and selecting "Network Conditions" from the "More tools" drop-down, then disabling automatic user agent selection. Switch it to something like "Safari—iPad iOS 9," then head to that URL again to get past the Media Creation Tool.

Next, download the version of Windows for which you have a key. The range of builds available on Microsoft's customer-facing website is relatively small, so if you're after something more obscure, head to https://uupdump.ml, and check out the files there. It's basically a non-official door into Microsoft's official update servers, meaning you can find Insider preview builds as well as cumulative updates, and the like. It can be a bit baffling, but it's a useful site—make sure you have Aria2 installed (https://aria2.github.io) if you want to download anything in ISO format.

ISOs are awkward to work with, given that they're essentially big sector-by-sector representations of optical media, rather than a traditional archive. So, double-click that ISO to mount it, and drag its contents to a folder on your PC—this is what we'll work on, before piecing it all back together at the end.

WHAT TO USE

With a stock ISO in hand, it's time to make a choice about just how you're going to prepare your custom version. You could go one of two ways. One, you could use an appropriate tool to dig into the files within the ISO and alter them; or two, you could install Windows on a suitable donor machine, tweak it there, and turn that installation back into a viable installable image. Each has its advantages. The former is the better choice if you're likely to want to take your custom Windows 10 install to multiple machines with different hardware configurations, while the latter is a commonly used enterprise tool, perfect for reimaging multiple machines with the same makeup—or one rig that's frequently reinstalled.

Since we're presuming you're building an ISO for generalized personal use, it's probably best to focus option one. But what to use? Microsoft's key tool is Deployment Image Servicing and Management, or DISM. It's part of Microsoft's deployment tools package, and primarily built to work on offline images, be they VHDs created from existing installations, or the WIM files found on Windows 10 ISOs that contain the core of the OS. And, while it's no doubt powerful, it's also one of those programs that would take an entire issue of *Maximum PC* to properly explain. Check out Microsoft's official resources at https://bit.ly/2IaJI5A if you'd like to find out more for yourself.

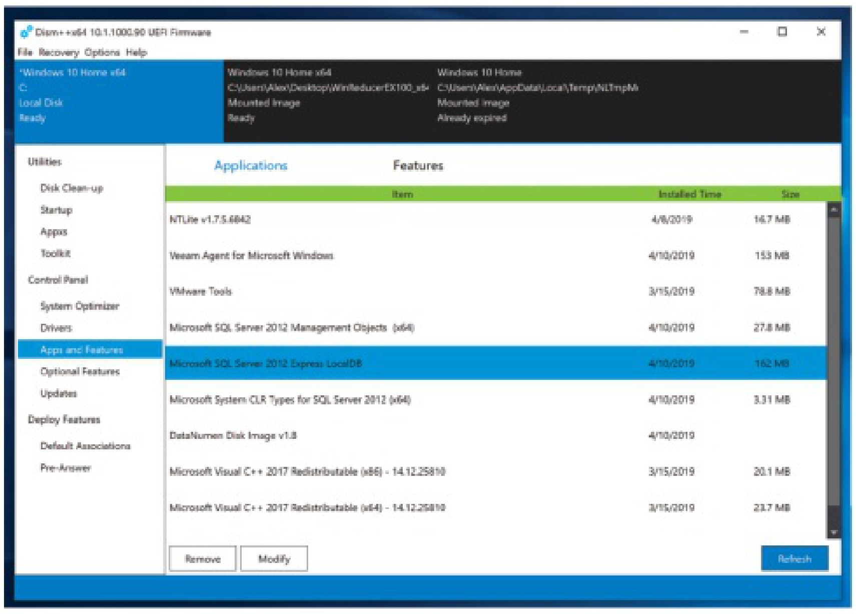
A few words of warning: Applying DISM tweaks, or any alterations for that matter, to an ISO is innocent enough, but using its extended features to mess around with a "production system" (read: your precious desktop) could be asking for trouble. These are powerful tools, capable of cutting out far more than you might actually think useful, and can tear a system apart if inadvertently set loose. Even shaving away components from an ISO can cause troubles down the line, because you may lack the prerequisites for Windows updates.

LOOKING GOOD

So, the good thing about DISM being a command-line tool is that you don't necessarily need to go in raw—there are interfaces out there with all the hard work built into them, and you just need to choose what you want to do. One of these is GUI-based DISM++ (though it apparently uses its own low-level code rather than piggybacking on DISM itself), which shows its Chinese heritage through occasional non-translated sections. Another is MSMG Toolkit, put together by the fine folks over at Major Geeks, which is similarly powerful, but rather obtuse, too.

Then there's NTlite. It is, by some margin, the most polished and powerful Windows precustomizer out there, having spawned from Windows XP tweaking tool Nlite, and grown in the subsequent five years since that was put out to pasture. Grab the installer from http://ntlite.com/download, install it, and select the Free license to start with—the full thing is unlocked

NTlite is the most polished and powerful Windows precustomizer, having spawned from Nlite, and grown in the five years since that was put out to pasture.


Dism++x64 10.1.1000.90 UEFI Firmware

File Recovery Options Help

*Windows 10 Home x64	Windows 10 Home x64	Windows 10 Home
C:	C:\Users\Alex\Desktop\WinReducerEX100_x64	C:\Users\Alex\AppData\Local\Temp\NLTmpMi
Local Disk	Mounted Image	Mounted Image
Ready	Ready	Already expired

Utilities
- Disk Clean-up
- Startup
- Appx
- Toolkit

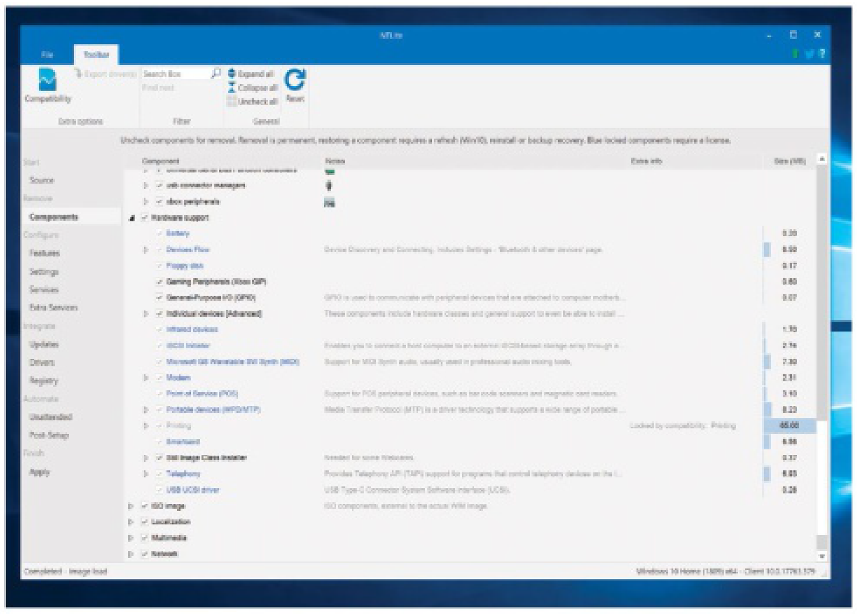
Control Panel
- System Optimizer
- Drivers
- Apps and Features
- Optional Features
- Updates

Deploy Features
- Default Associations
- Pre-Answer

Applications | Features

Item	Installed Time	Size
NTLite v1.7.5.6842	4/8/2019	16.7 MB
Veeam Agent for Microsoft Windows	4/10/2019	153 MB
VMware Tools	3/15/2019	78.8 MB
Microsoft SQL Server 2012 Management Objects (x64)	4/10/2019	27.8 MB
Microsoft SQL Server 2012 Express LocalDB	4/10/2019	162 MB
Microsoft System CLR Types for SQL Server 2012 (x64)	4/10/2019	3.31 MB
DataNumen Disk Image v1.8	4/10/2019	
Microsoft Visual C++ 2017 Redistributable (x86) - 14.12.25810	3/15/2019	20.1 MB
Microsoft Visual C++ 2017 Redistributable (x64) - 14.12.25810	3/15/2019	23.7 MB

DISM++ is very powerful, with an interface designed by a sadist.



Blue items are locked down in NTLite's free edition.

with a 40 euro (around $45) yearly fee, so don't stump up the cash until you're sure it can do what you're looking for. NTLite can work on live Windows installations, but for our purposes, we'll stick to tweaking the ISO we prepared earlier. Click "Add," then select "Image Directory," and point it at the directory containing your Windows installer file—you should see a list of the operating systems included within the "install.wim" file in the ISO directory. We should mention at this point that the WIM (or Windows Image) file is the bit we're really working on here—the rest of the ISO is pretty tangential to this task.

Double-click the version you're looking to work on, and NTLite mounts it internally, which may take a while depending on your hardware. Once it's turned green, head to the left column, and click "Components." Read the stern warning, hit "OK," and you're into the meat of it. Expand the categories—everything the Free version of NTLite doesn't allow you to remove is labeled in blue, but there's plenty that can be cut without stumping up any cash.

WHAT TO DROP

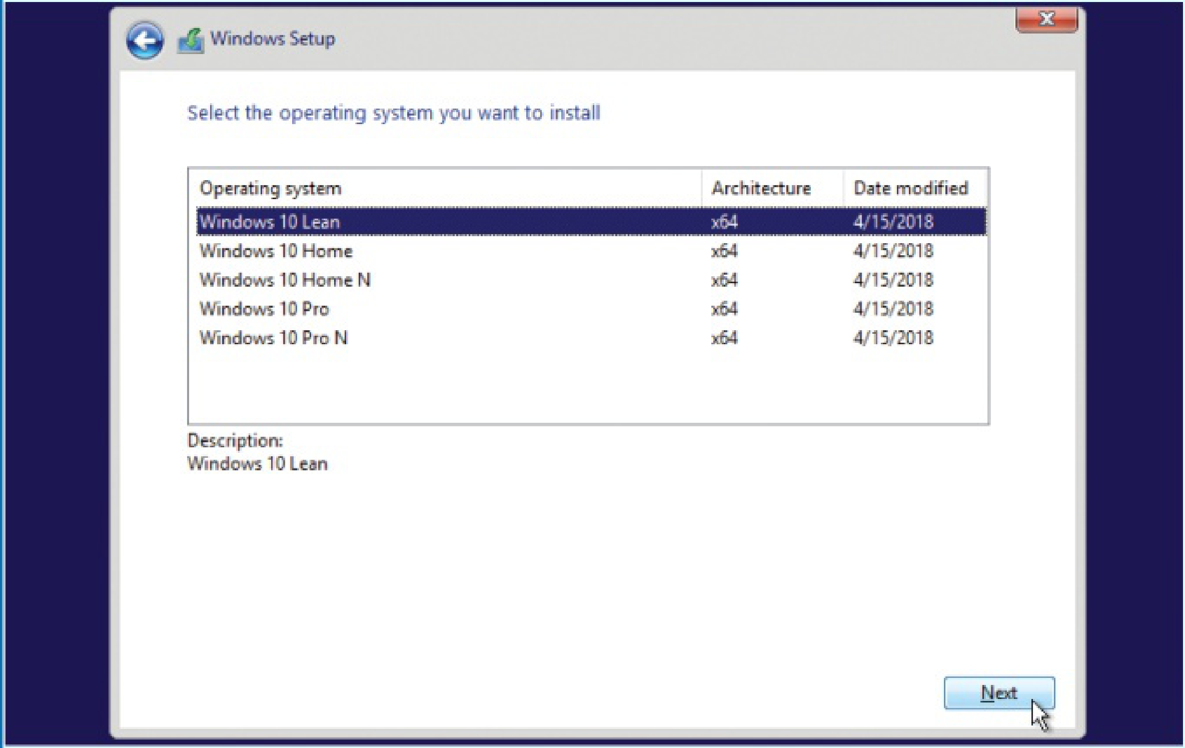
First, and most obviously, head to the bottom of the list, expand "Windows Apps," then open up the "Apps" section. Getting rid of these isn't going to cut a large amount of size from your eventual ISO, but it'll certainly clean up your "Start" menu, and stop the irritation of unified platform apps opening up your files when

GETTING LEAN

Not that we're about to suggest that cutting down an ISO to its bare minimum is a complete waste of time, but there is an alternative (of sorts) officially sanctioned by Microsoft itself. It's called, appropriately, Windows 10 Lean.

Intended to be used on tablets with 16GB of storage, Windows 10 Lean cuts the installer size by a hefty 2GB over Windows 10 Pro, and takes up only 6.5GB of drive space when installed —around half the usual average Windows footprint. There's not much in there beyond Windows itself (only around 200MB of the Lean install is taken up by apps), and it's very much a modern-only OS; while you can install standard x86 applications, unlike the old Windows RT, basically every legacy component is gone. Control Panel, for example, is present, but eerily empty.

Bad news, however, or perhaps good news if you've put in the effort to trim your own ISO: Although it appeared in Insider Preview build 17650, Lean hasn't been seen since, and it's disappeared from Microsoft's UUP servers. That particular build is out there if you look for it, though, and we would be very surprised if it (or something similar) didn't appear in future Windows 10 builds.


Windows Setup

Select the operating system you want to install

Operating system	Architecture	Date modified
Windows 10 Lean	x64	4/15/2018
Windows 10 Home	x64	4/15/2018
Windows 10 Home N	x64	4/15/2018
Windows 10 Pro	x64	4/15/2018
Windows 10 Pro N	x64	4/15/2018

Description:
Windows 10 Lean

Windows 10 IoT Core runs on just 2GB of storage, and is designed for embedding, so can run on tiny devices like the Raspberry Pi. It's not Windows as you know it—there's no command prompt, no desktop, and its GUI is limited to running one Microsoft universal platform app at a time—but it's free. Download it, and find documentation, at www.microsoft.com/en-us/software-download/windows10IoTCore.

you'd prefer something more personal. Besides, when was the last time you used Windows' built in Tips app? You'll notice some older naming conventions used here—ZuneMusic in place of the Groove Music rebrand, for example—but we're confident you'll be able to muddle your way through. Pay special attention to the "Notes" and "Dependencies" columns on the right, which let you know when two apps or features are inextricably linked. Get rid of one, and the other will no longer function; with just about everything in the "Components" section, as soon as you've unchecked it and created your new ISO, that decision is final.

Head down and look at "System Apps." There are a few things here that you may not have thought of removing: You could slice out File Explorer, if you're a masochist, but we're more thinking XboxGameCallableUI (the Game Bar), Windows Defender (the antivirus and antimalware components of Windows Security Center), Parental Controls, and other features you might never use or may have an alternative in hand. Again, no guarantees about what combinations are going to work smoothly or not.

INLINE TWEAKS

Wading through NTLite's "Configure" section, specifically "Features" and "Settings," reveals another reason you might want to create your own installer: You can get it just so without the tedious practice of aligning your visual preferences every time you hit that new desktop, or you could automatically switch on those features you know you're going to need, and disable those you don't. Admittedly, checking through every minute option to make sure you've got everything can take a while, but two or three installations down the line, it'll prove to be worth the effort. We'd treat the "Services" and "Extra Services" sections with extreme kid gloves, though, particularly with regards to disabling what could be crucial system components. If you're running on older hardware, this could be one of the sections that makes the biggest difference on Windows load times, but it's also a sure-fire way to break everything if you're clumsy. Check out the "Safe Services" box below to find out what's definitely OK to block.

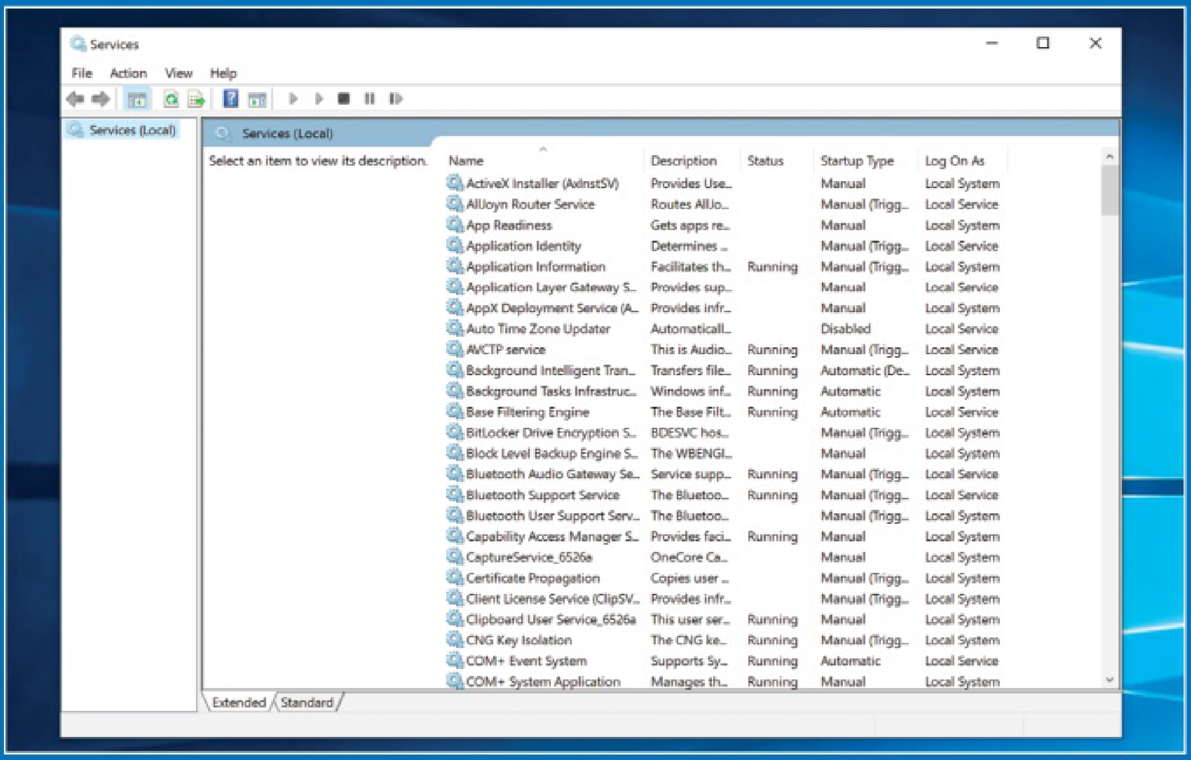
Next comes the "Integrate" section. Head to "Updates," click the "Add" button, and select "Latest online updates." NTLite goes hunting on Microsoft's servers for the most recent incremental upgrades to the specific version of Windows 10 that you're currently working on—click "Enqueue" to get them downloading and added to the integration queue, ready to be mixed in with the rest of Windows 10 at the final stage. If you have specific hardware drivers you'd like to build into your ISO, you can point to them by clicking the "Add" button within the "Drivers" section.

NTLite's automation section is the place for real time-savers: If you choose to turn on unattended installation by clicking the "Enable" radio button, you can make all the choices you would usually have to laboriously click through before you reach the desktop for the first time. Just double-click an option to set it, and right-click it and select "Reset value" should you make a mistake. "Post-setup" lets you select software you want to install upon first boot; gather together the installer executables you're likely to use (or, even better, download a big package of them with a fully automated installer from http://ninite.com), and add them in here. You can also use it to run through command-line tweaks, either by using the couple that are built in or configuring your own.

BUILD IT

The "Apply" section, at the bottom of NTLite's left-hand list, is where the real magic happens, or at least where you turn the options you've clicked into a real ISO. We recommend selecting

SAFE SERVICES

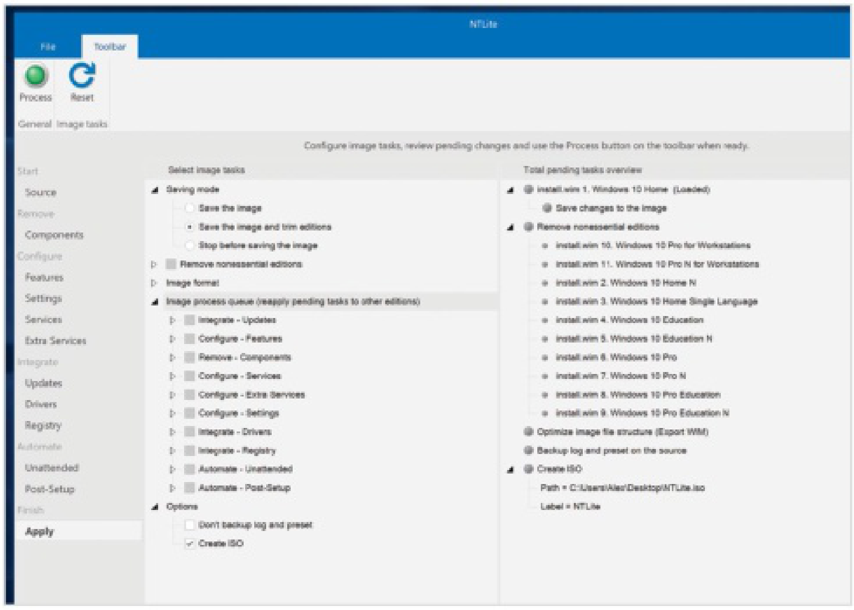


Select an item to view its description.

Name	Description	Status	Startup Type	Log On As
ActiveX Installer (AxInstSV)	Provides Use…		Manual	Local System
AllJoyn Router Service	Routes AllJo…		Manual (Trigg…	Local Service
App Readiness	Gets apps re…		Manual	Local System
Application Identity	Determines …		Manual (Trigg…	Local Service
Application Information	Facilitates th…	Running	Manual (Trigg…	Local System
Application Layer Gateway S…	Provides sup…		Manual	Local Service
AppX Deployment Service (A…	Provides infr…		Manual	Local System
Auto Time Zone Updater	Automaticall…		Disabled	Local Service
AVCTP service	This is Audio…	Running	Manual (Trigg…	Local Service
Background Intelligent Tran…	Transfers file…	Running	Automatic (De…	Local System
Background Tasks Infrastruc…	Windows inf…	Running	Automatic	Local System
Base Filtering Engine	The Base Filt…	Running	Automatic	Local Service
BitLocker Drive Encryption S…	BDESVC hos…		Manual (Trigg…	Local System
Block Level Backup Engine S…	The WBENGI…		Manual	Local System
Bluetooth Audio Gateway Se…	Service supp…	Running	Manual (Trigg…	Local Service
Bluetooth Support Service	The Bluetoo…	Running	Manual (Trigg…	Local Service
Bluetooth User Support Serv…	The Bluetoo…		Manual (Trigg…	Local System
Capability Access Manager S…	Provides faci…	Running	Manual	Local System
CaptureService_6526a	OneCore Ca…		Manual	Local System
Certificate Propagation	Copies user …		Manual (Trigg…	Local System
Client License Service (ClipSV…	Provides infr…		Manual (Trigg…	Local System
Clipboard User Service_6526a	This user ser…	Running	Manual	Local System
CNG Key Isolation	The CNG ke…	Running	Manual (Trigg…	Local System
COM+ Event System	Supports Sy…	Running	Automatic	Local Service
COM+ System Application	Manages th…	Running	Manual	Local System

What can you disable without risking the integrity of your system? Given the large number of Windows 10 services, the safe list is surprisingly short, but it can make a big difference to system efficiency. You can safely set Print Spooler to disabled if you don't intend to use a printer, or IP Helper if you'll be sticking to IPv4 and don't mind dropping IPv6 compatibility. If you don't use workgroups, TCP/IP NetBIOS Helper is safe to drop, and if you're not networking at all, the Distributed Link Tracking Client can be disabled. Note that using NTLite for this (as an example) doesn't remove these services, it just switches them off. You can perform the same actions on a running system through the Administrative Tools section of Control panel.

Other things that won't cause problems when disabled are: the trio of Connected User Experiences and Telemetry, Diagnostic Policy Service, and Diagnostic Tracking Service (if you drop one, drop all three); Downloaded Maps Manager (because you probably don't use Microsoft's own Maps app); Program Compatibility Assistant Service (you'll get hassled a lot less without this one); Remote Registry (disabling this is a good thing in terms of security); Secondary Logon; Touch Keyboard and Handwriting Panel Service (unless you're installing on a tablet); Windows Defender Service (depending on if you're running your own AV solution); Windows Error Reporting Service; Windows Image Acquisition (WIA) (only relevant if you use a scanner or AIO printer); and Windows Search (drop this only if you know your way around your hard drive and are meticulously neat).

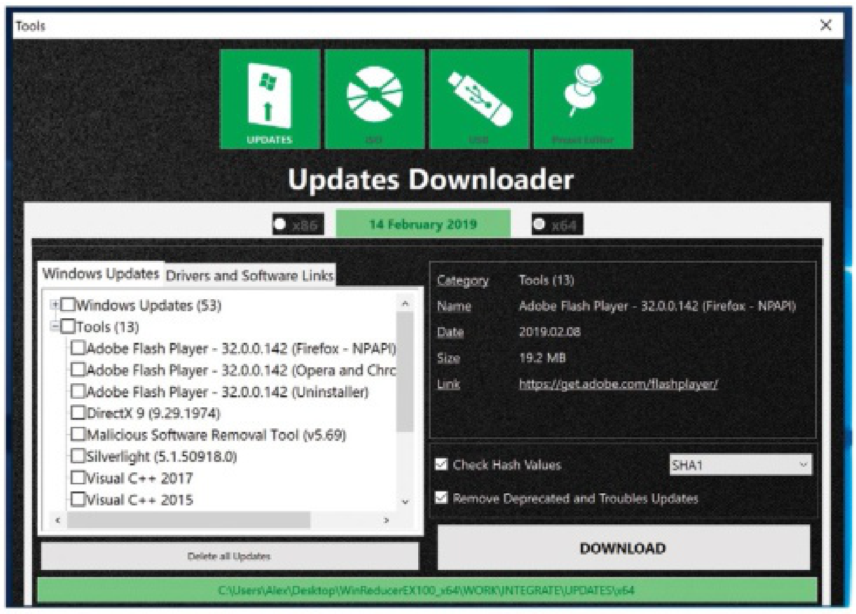


Configure image tasks, review pending changes and use the Process button on the toolbar when ready.

Select image tasks
- Saving mode
  - ○ Save the image
  - ● Save the image and trim editions
  - ○ Stop before saving the image
- ☐ Remove nonessential editions
- Image format
- Image process queue (reapply pending tasks to other editions)
  - ☐ Integrate - Updates
  - ☐ Configure - Features
  - ☐ Remove - Components
  - ☐ Configure - Services
  - ☐ Configure - Extra Services
  - ☐ Configure - Settings
  - ☐ Integrate - Drivers
  - ☐ Integrate - Registry
  - ☐ Automate - Unattended
  - ☐ Automate - Post-Setup
- Options
  - ☐ Don't backup log and preset
  - ☑ Create ISO

Total pending tasks overview
- install.wim 1. Windows 10 Home (Loaded)
  - Save changes to the image
- Remove nonessential editions
  - install.wim 10. Windows 10 Pro for Workstations
  - install.wim 11. Windows 10 Pro N for Workstations
  - install.wim 2. Windows 10 Home N
  - install.wim 3. Windows 10 Home Single Language
  - install.wim 4. Windows 10 Education
  - install.wim 5. Windows 10 Education N
  - install.wim 6. Windows 10 Pro
  - install.wim 7. Windows 10 Pro N
  - install.wim 8. Windows 10 Pro Education
  - install.wim 9. Windows 10 Pro Education N
- Optimize image file structure (Export WIM)
- Backup log and preset on the source
- Create ISO
  - Path = C:\Users\Alex\Desktop\NTLite.iso
  - Label = NTLite

Trim out editions you don't need, and build media you can work with.



- ☐ Windows Updates (53)
- ☐ Tools (13)
  - ☐ Adobe Flash Player - 32.0.0.142 (Firefox - NPAPI)
  - ☐ Adobe Flash Player - 32.0.0.142 (Opera and Chrc
  - ☐ Adobe Flash Player - 32.0.0.142 (Uninstaller)
  - ☐ DirectX 9 (9.29.1974)
  - ☐ Malicious Software Removal Tool (v5.69)
  - ☐ Silverlight (5.1.50918.0)
  - ☐ Visual C++ 2017
  - ☐ Visual C++ 2015

Category Tools (13)
Name Adobe Flash Player - 32.0.0.142 (Firefox - NPAPI)
Date 2019.02.08
Size 19.2 MB
Link https://get.adobe.com/flashplayer/

☑ Check Hash Values SHA1
☑ Remove Deprecated and Troubles Updates

C:\Users\Alex\Desktop\WinReducerEX100_x64\WORK\INTEGRATE\UPDATES\x64

WinReducer is very powerful, but could do with a design overhaul.

"Save the image and trim editions," unless you're flush with keys for all kinds of Windows versions, because this chops away any files not explicitly required for the version you're configuring. At the bottom of the tasks list, check the box that says "Create ISO." If you don't, NTLite instead simply produces a new install.wim file (the guts of a Windows installer), which may be handy if you're looking to deploy from, say, an existing Windows install USB or a network location. Click "Process," and you create that ISO—but not before disabling Windows Defender on your existing machine to speed up the process. Again, this isn't 100 percent required, but it's safe enough to switch it off while NTLite grinds away. When your ISO is complete, you can write it in whatever way you see fit—we recommend using Rufus (http://rufus.ie) to put it on a USB stick.

MORE EXTREME

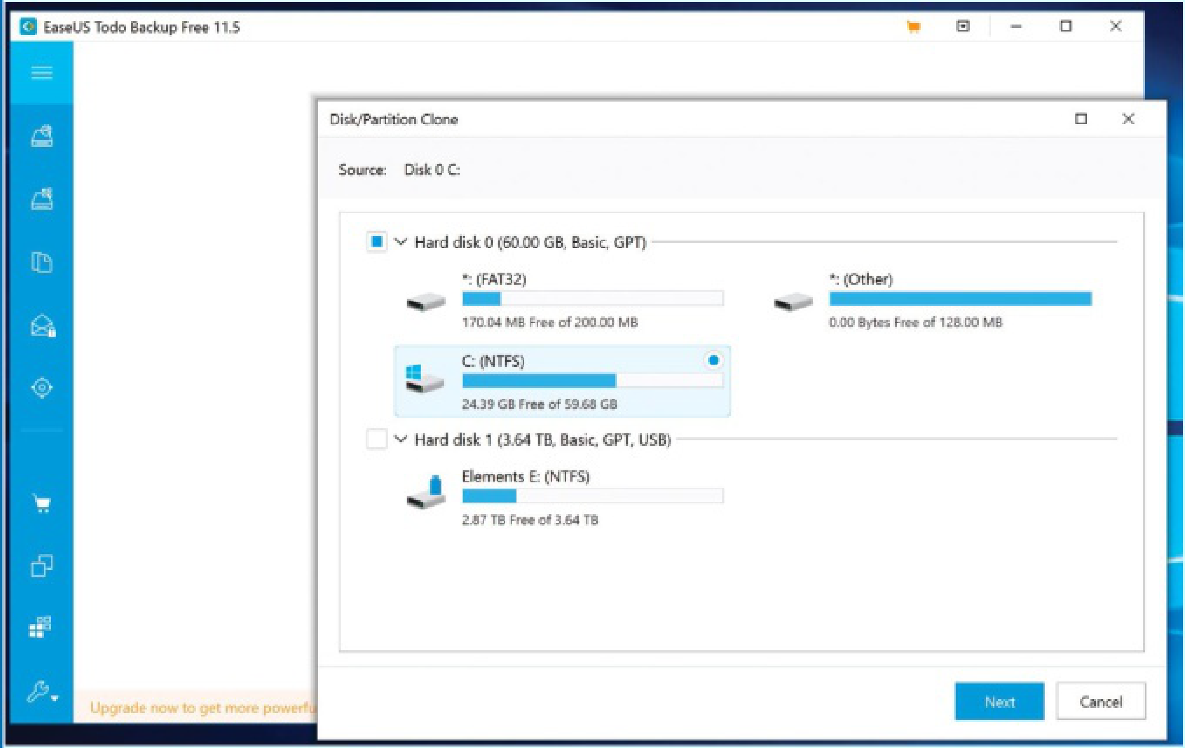
A final mention to another tool: WinReducer. It's ugly, crude, and wants you to pay for an activation key (from around $11 for six months), but it's well regarded for its ability to hack chunks away from Windows 10 ISOs and toss them in the trash. If that's your goal, its remover gives you access to 1,265 Windows items—and there's an automated removal preset designed to optimize the size of its output ISO without cutting down on features too heavily. If NTLite is a bit much, WinReducer could be just the thing. ⏻

IMAGING AN EXISTING SYSTEM

The alternative goes like this: Install Windows 10 as usual on a sacrificial machine (or a sacrificial drive), making sure everything stays on your C: drive. Configure it using the standard tools. Set up your favorite user accounts, your visual settings, install your software, and disable whatever you want disabled. Then turn it into something you can move elsewhere.

There are a few ways to do this, but creating an ISO isn't the most sensible. Nor is wrestling with DISM at the command prompt of a Windows installer, or creating some kind of Windows PE boot media. You'd be better off running something like Macrium Reflect or EaseUs ToDo Backup, both of which include bootable backup environments, and exporting the contents of your hard drive to a system image on an external disk. On your target machine, just restore that disk image, reactivate it with a new key, and you're good to go.

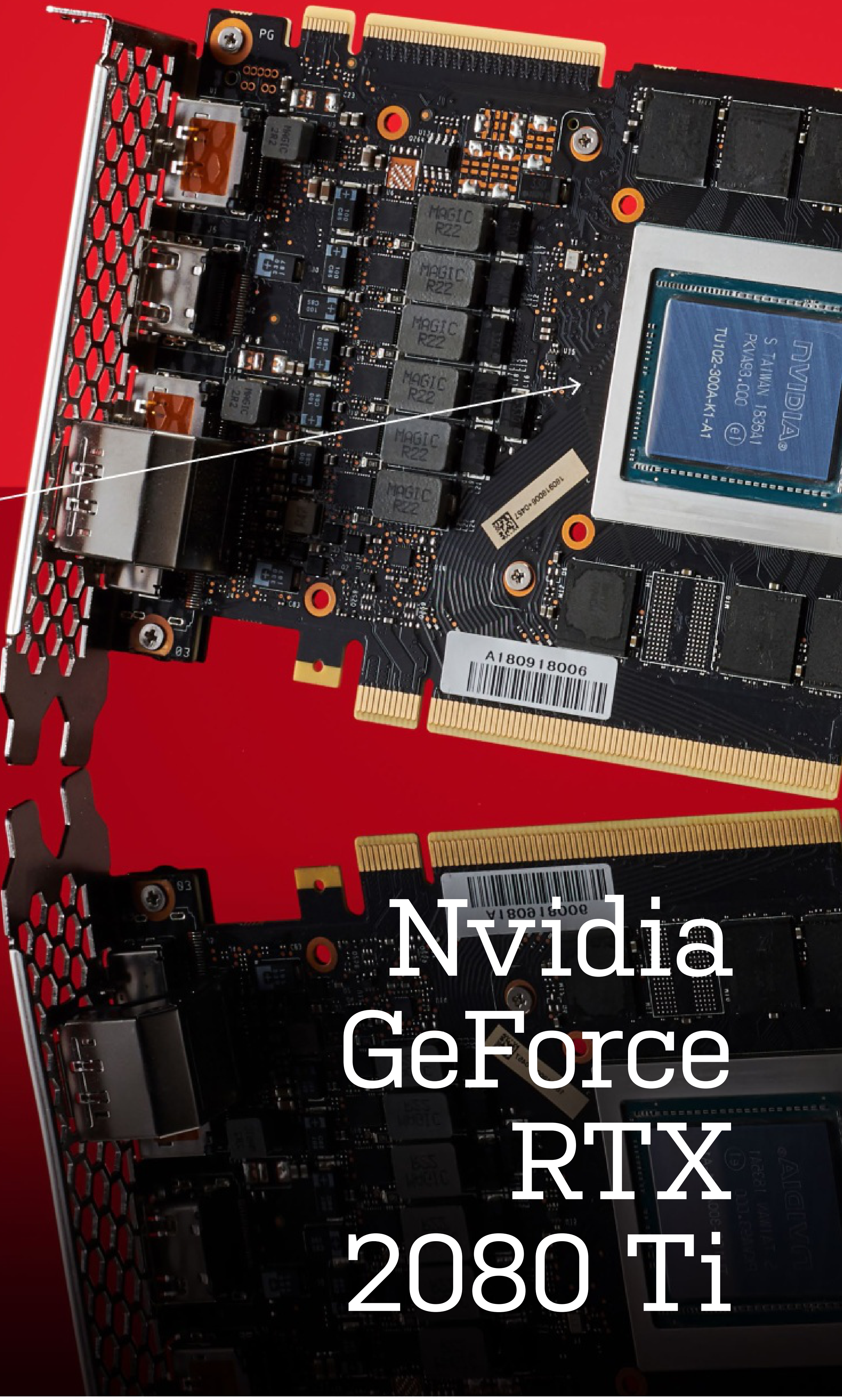
Frankly, while this is possible and feasible if you're using the same hardware on both machines (or just want to roll back the same machine to its original settings), it's less practical for these purposes than preconfiguring and preloading a Windows 10 ISO. Porting an existing install, particularly one that's already been activated with a product key, to a machine with differing hardware can cause problems, and might even mean a sheepish call to Microsoft's beleaguered activation representatives if your OS decides you're up to no good. Making regular backups is A Good Thing, and you should totally do that, but leave system imaging to those poor IT departments with fleets of identical hardware to maintain.



Source: Disk 0 C:

- ■ Hard disk 0 (60.00 GB, Basic, GPT)
  - *: (FAT32) 170.04 MB Free of 200.00 MB
  - *: (Other) 0.00 Bytes Free of 128.00 MB
  - C: (NTFS) 24.39 GB Free of 59.68 GB ●
- ☐ Hard disk 1 (3.64 TB, Basic, GPT, USB)
  - Elements E: (NTFS) 2.87 TB Free of 3.64 TB

TECH PORN

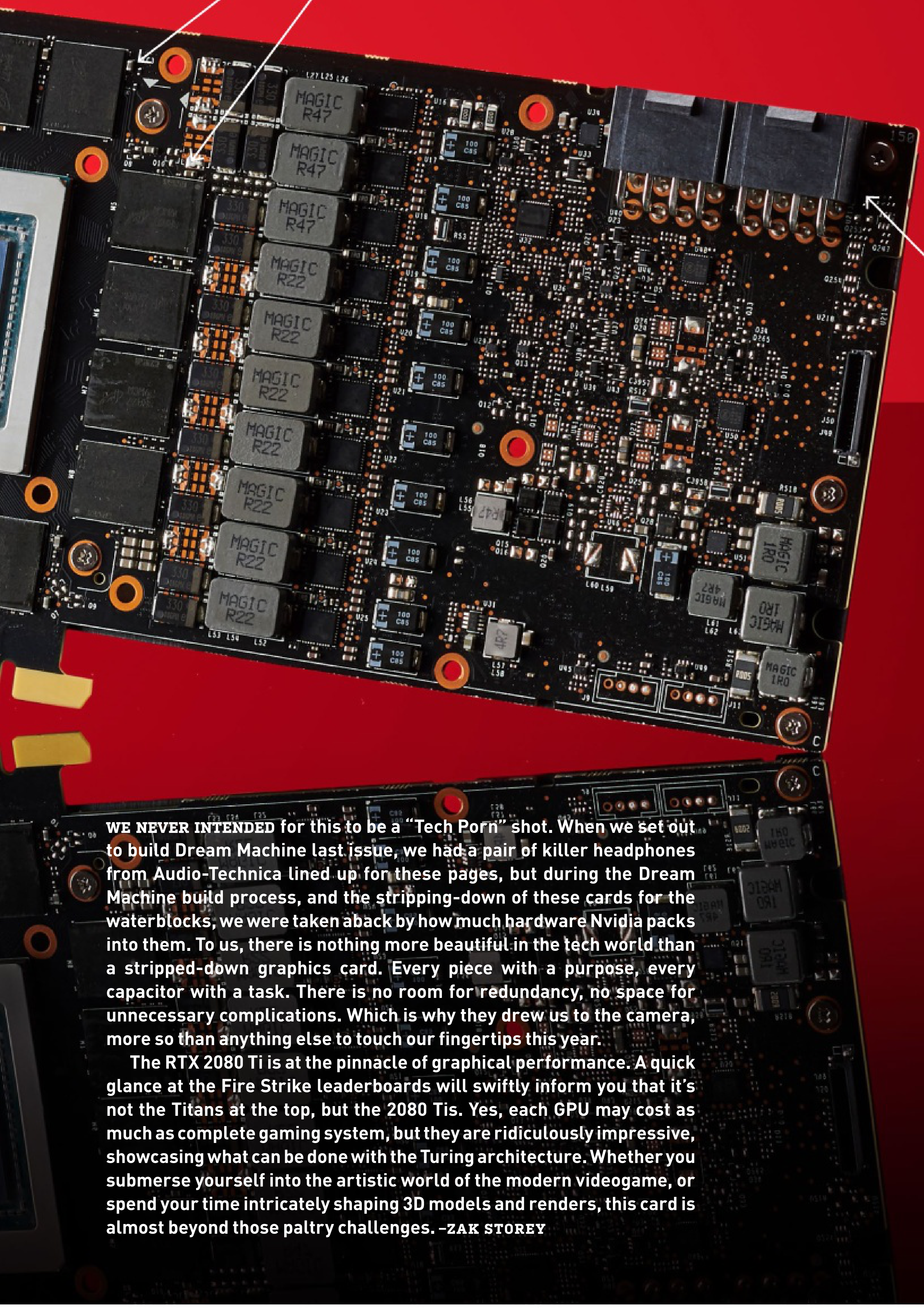

PG
MAGIC R22
NVIDIA
S TAIWAN 1835A1
PKVA93.C00
TU102-300A-K1-A1
A180918006

Nvidia GeForce RTX 2080 Ti

1 RTX HEART
There's a total of 68 ray-tracing cores buried inside here—22 more than the RTX 2080, and only four fewer than a Titan RTX. To give you some numbers, if this processor didn't have ray-tracing cores, it should house around 15 billion transistors. It actually has 18.6 billion. That's 20 percent of the hardware dedicated to ray tracing.

2 11GB GDDR6

To denote how similar this card is to the Titan RTX, there's a single memory chip missing. Aside from that absent 1GB, there's little else between the two, except a few disabled shader processors (down from 4,608 to 4,352), and slightly fewer ray-tracing cores.



3 POWER MANAGEMENT

The standard Founders Edition card comes with some seriously impressive power management hardware. In fact, each eight-pin PCIe power is supplied with five phases, and then there's a further three phases that handle the PCIe slot's juice, giving us a 13-phase design.

WE NEVER INTENDED for this to be a "Tech Porn" shot. When we set out to build Dream Machine last issue, we had a pair of killer headphones from Audio-Technica lined up for these pages, but during the Dream Machine build process, and the stripping-down of these cards for the waterblocks, we were taken aback by how much hardware Nvidia packs into them. To us, there is nothing more beautiful in the tech world than a stripped-down graphics card. Every piece with a purpose, every capacitor with a task. There is no room for redundancy, no space for unnecessary complications. Which is why they drew us to the camera, more so than anything else to touch our fingertips this year.

The RTX 2080 Ti is at the pinnacle of graphical performance. A quick glance at the Fire Strike leaderboards will swiftly inform you that it's not the Titans at the top, but the 2080 Tis. Yes, each GPU may cost as much as complete gaming system, but they are ridiculously impressive, showcasing what can be done with the Turing architecture. Whether you submerse yourself into the artistic world of the modern videogame, or spend your time intricately shaping 3D models and renders, this card is almost beyond those paltry challenges. –**ZAK STOREY**

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including the best tips, tricks and tutorials!

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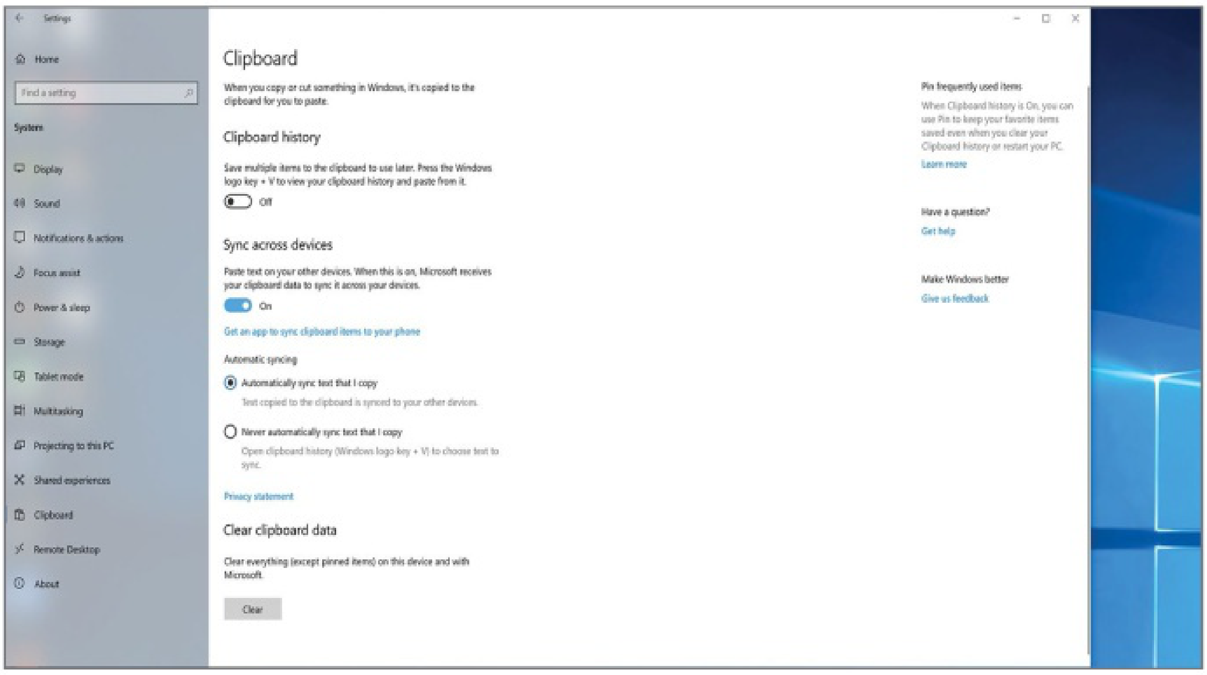
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH



Clipboard

When you copy or cut something in Windows, it's copied to the clipboard for you to paste.

Clipboard history

Save multiple items to the clipboard to use later. Press the Windows logo key + V to view your clipboard history and paste from it.

Off

Sync across devices

Paste text on your other devices. When this is on, Microsoft receives your clipboard data to sync it across your devices.

On

Get an app to sync clipboard items to your phone

Automatic syncing

● Automatically sync text that I copy

Text copied to the clipboard is synced to your other devices.

○ Never automatically sync text that I copy

Open clipboard history (Windows logo key + V) to choose text to sync.

Privacy statement

Clear clipboard data

Clear everything (except pinned items) on this device and with Microsoft.

Clear

Pin frequently used items

When Clipboard history is On, you can use Pin to keep your favorite items saved even when you clear your Clipboard history or restart your PC.

Learn more

Have a question?

Get help

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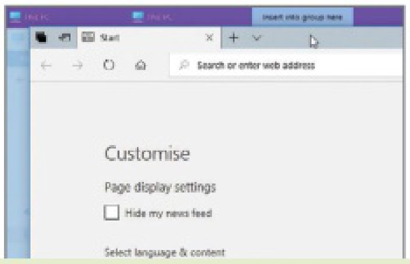
SYNC YOUR CLIPBOARD ACROSS MULTIPLE DEVICES

Windows 10 has had the option to save clipboard data to the cloud for a while, but it isn't enabled by default. To turn it on, simply jump into the Settings menu, then find it under "System → Clipboard," and turn on the "Sync across devices" option. This will save copied text to the cloud, and enable you to paste it instantly on your other Window-enabled devices.

MAKE – USE – CREATE

56
Build your own Raspberry Pi stop-motion studio



64
Clear away your desktop clutter with Groupy

70
A $1,025 GTX 1660 Ti-based 1080p gaming powerhouse

CHRISTIAN GUYTON
STAFF WRITER

RUNNING THE TESTS

The new GTX 1660 GPUs have had us polarized; are they a stellar upgrade for 1080p gaming builds, or an awkward stopgap between 10 and 20-series cards? We've snagged a 1660 Ti for this month's "Build It," and it was smooth sailing. We don't want to spoil anything—you can skip ahead a few pages and read it right now, if you're so inclined—but we'd like to say it went pretty well.

No doubt there will be some hot discussions about the value of the 1660. For gamers with aging pre-960 graphics cards, it could be a godsend—particularly given its mainstream price. But if you're rocking a 1060 or better, it's a difficult to recommend this newcomer. Sales will tell the tale, though—Nvidia must have high hopes for the 1660, as it hasn't quite gone for a budget price.

Elsewhere, we're reviewing RAM for the first time in ages. We remembered why we hadn't done it for so long—benchmarking RAM takes time, and had us mashing buttons in frustration on our test motherboard. We got there in the end, but only after several grumpy glares at the "estimated time remaining" field in 7zip. There's no reason it should be so difficult, we told ourselves, as we wrestled with the BIOS for the eighth time.

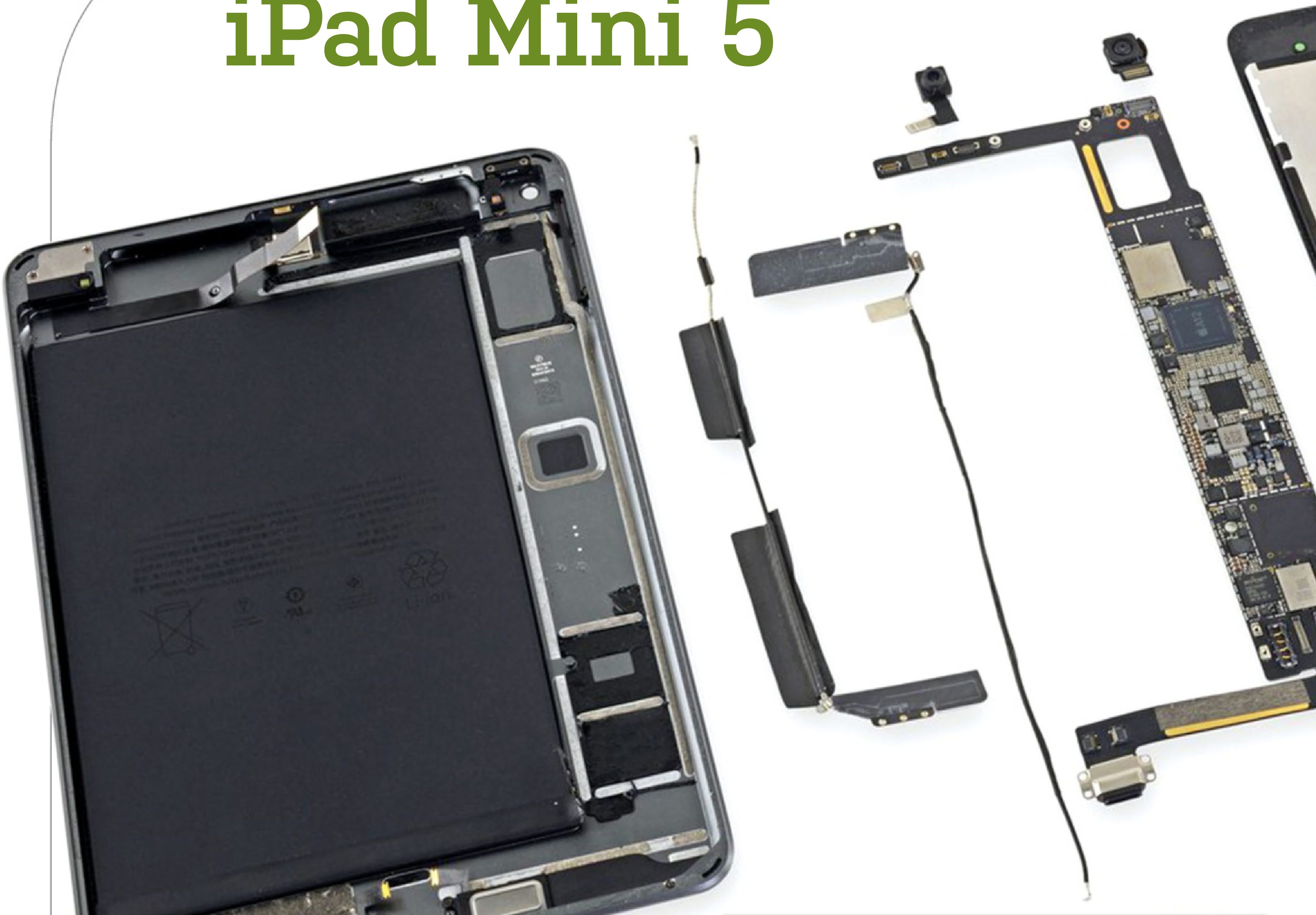
↘ submit your How To project idea to: comments@maximumpc.com

IFIXIT presents:

AUTOPSY

THIS MONTH WE DISSECT...

iPad Mini 5



The camera is a pretty significant upgrade from the 1.2MP sensor found in the Mini 4.

About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products.
To learn more, visit www.ifixit.com.

We're just dealing with standard Phillips heads here.

BACKGROUND

What's that on our teardown table? It's a big phone! A small tablet! AirPower? No, it's the iPad Mini! This year, Apple revisited its smallest tablet, bucking industry trends by keeping the Mini's screen small and bezels big. Did Apple stick to tradition all around, or will we be treated to an interior redesign? We'll have to tear it down to find out!

MAJOR TECH SPECS

- 7.9-inch LED-backlit Retina True Tone display with 2048×1536 resolution (326 ppi)
- A12 Bionic SoC with 64-bit architecture and embedded M12 coprocessor
- 8MP rear camera and 7MP FaceTime HD camera
- Wi-Fi with dual-channel (2.4GHz and 5GHz) and MIMO support, plus Bluetooth 5.0
- 19.1Wh rechargeable lithium-polymer battery
- Three-axis gyro, accelerometer, barometer, and ambient light sensor

KEY FINDINGS

- From the outside, this new Mini looks exactly like a downsized version of the equally new iPad Air. Spoiler alert: Judging by our X-rays, it's not. It looks exactly like an upgraded iPad Mini 4. We pull a cellular-capable iPad Mini 4 from the lab to confirm our suspicions. Headphone jack: check. Big bezels: check. Home button: check.
- As much as we wish Apple would come up with a better approach to tablet construction, we reckon we know how opening this will go: Heat. Slash. Repeat. Once the Mini is shucked, we get our first peek at the internals. We remove the bracket covering the display and battery connectors, and it brings along a friend. The battery flex connector is now adhered to that bracket, automatically disconnecting the battery. Nifty! Hopefully, this will help fixers to not accidentally kill the backlight on their displays.
- This Mini has a different battery model to its predecessor, with updated (i.e. incompatible) connectors. Rated for 19.32Wh, it matches the previous Mini's, has less than the standard iPad's 32.9Wh, and is just over the Galaxy Note9's 15.4Wh. iPads still lag behind iPhones in construction—the home button being an example. On iPhones, this is an easy, elegant swap, but here it's still a mess of glue.
- This Mini inherits the 7MP f/2.2 front-facing camera setup we first saw in the 10.5-inch iPad Pro. With the cameras out of the way, we get a close look at the new upper microphone array, now centered near the selfie cam.
- The iPad Mini continues to be its own entity—not quite a shrunken-down iPad, nor a miniature iPad Air. After a number of conflicting experiences ultimately leading up to this Mini's glued-in battery, we're no longer optimistic about seeing adhesive pull tabs for iPad batteries.
- Repairability score: 2 out of 10 (10 is the easiest to repair). A single Phillips driver takes care of all the screws. Many components are modular and can be replaced independently, but the Lightning port is soldered to the logic board. Battery replacement is possible, but still difficult. Gobs of adhesive hold many parts and cables in place, complicating repairs. Removing the home button is tough, and will be required for display replacement if you want to keep Touch ID functionality. ⏻

Build a Raspberry Pi Stop-Motion Studio

YOU'LL NEED THIS

RASPBERRY PI 2 OR LATER
With Raspbian Stretch, Pi Camera module, dual-state push button, breadboard, monitor, mouse and keyboard, and tripod/secure mount.

SOMETHING TO ANIMATE
Clay models, Lego, action figures, and so on.

EVER SAT GUFFAWING AT TERRY GILLIAM'S BIZARRE SUBVERSION of Victorian-era greetings cards in *Monty Python's Flying Circus*, or egging on unlikely heroes Wallace and Gromit? Then chances are you've spent a few moments thinking about how those animations are made.

There was a time when stop-motion photography was beyond the reach of most people. Overhead cameras mounted on rostrums were expensive, and unless your school or college had one, your best bet was to take some photos and make a flick-book instead. As with everything, time and technology have revolutionized the production of stop-motion photography, and now making a movie with a digital camera or mobile device is child's play.

The Raspberry Pi Camera module offers a superb low-cost digital option. While time-lapse photography is popular, it's easy to overlook its illusory bedfellow. After all, creating a stop-motion animation with figures, household objects, or simply toys is intensive work.

Often the results aren't very good, and even getting to the point where you have enough shots to create a short movie clip can be pretty back-breaking. Fortunately, there are some shortcuts you can take, which we'll explain here. –CHRISTIAN CAWLEY

1 STOP, IT'S MOTION TIME...

It's a good idea to allocate time to your stop-motion project—a few days, say. Shoots are famously slow; you're going to be taking around 24 frames for each second of footage, so having an area that remains undisturbed when you're not using it is vital. This "hot set" should remain untouched by others, too.

›› Your studio area should have enough space for the tripod- or rostrum-mounted Raspberry Pi and Camera module, along with the objects you're filming. In the case of 2D paper-based animation, this should be an area of table big enough to fill, or almost fill, the lens. Also useful for overhead shooting is a sheet of clear plastic or glass. This keeps the papercraft pieces in place when taking a shot, as well as helping them to look flat and uniform, and dealing with any curled edges. If it was good enough for Terry Gilliam, it's good enough for you!

›› In order to shoot clay models, fruit, toys, or whatever 3D objects you plan to animate, you need an area large enough to build a set [**Image A**]. There should also be space around the table for you to move in to aid with the animation of your characters. Remember that stop-motion animation requires very slight movements in every frame for each of the characters or objects you're shooting. The aim is to get the character from one position to another, while creating the illusion of motion. Access to the character from every angle helps you to achieve this.

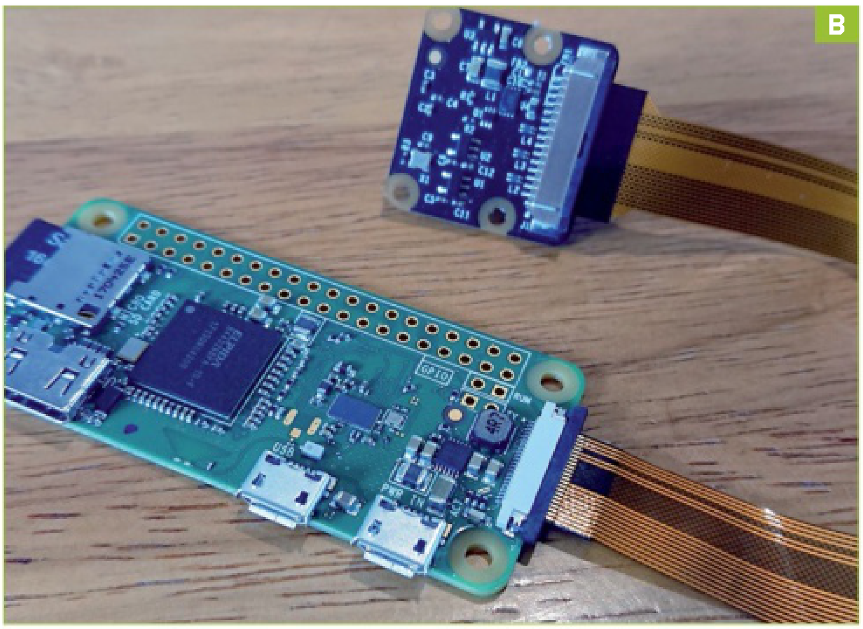
›› Whether you're using an overhead camera or a standard tripod-mounted shoot, the project needs to be well lit. See the "Lighting Balance" box (pg. 58) for some handy lighting tips.

2 LIGHTS!

To turn your Raspberry Pi into the central component of your stop-motion studio, you need to attach a camera. While USB cameras work fine, it's far more satisfying to employ the latest Raspberry Pi Camera module [**Image B**].

›› Connecting this device to the Raspberry Pi requires you to insert the ribbon cable into the "Camera" connector on the SBC. If you're using a Raspberry Pi model B, the shiny side of the ribbon should face away from the Ethernet port.

›› For Raspberry Pi Zero devices with a camera port, the shiny side of the ribbon should face up. Take care to correctly unclip the catch on these connectors before



inserting the ribbon. Similarly, ensure the catch is correctly secured afterward.

» Boot up the Pi and enter the configuration screen on the desktop ("Menu → Preferences → Raspberry Pi Configuration"), or open a terminal and enter `sudo raspi-config`. Here, select "Interfaces" (or "Interfacing Options" in the terminal), then enable "Camera." Click "OK" to confirm and restart your Pi.

» With the Pi restarted, open a terminal window, and enter `raspistill -o image1.jpg`. This should take a photo from the camera, confirming the device is correctly connected and working. You'll notice that raspistill is built into the Raspbian operating system. It's part of the raspicam software, which we'll come back to later.

3

CAMERA!

Setting up the camera on your Raspberry Pi will enable you to create a stop-motion video, but it can be a bit awkward entering the same command for every single shot. The solution? Create a shutter button that you can connect to your Raspberry Pi.

» Prototype it first using a breadboard, connecting the two wires to pins 6 and 11 on the GPIO header (or GND and GPIO17) [**Image C**]. With the button correctly mounted to connect to the wires, you can use this setup to capture each frame. Alternatively, connect a wired-up button directly to the pins on your Raspberry Pi's GPIO.

» However you connect the shutter button, you then need to create a Python script to detect it. Each push of the button captures and saves a new photo to the specified directory. Open "Menu → Programming → Python 3 (IDLE)," then "File → New." In the resulting window, input this script, from Raspberrypi.org (http://bit.ly/2IJeu6q):

```
from picamera import PiCamera
from time import sleep
from gpiozero import Button

button = Button(17)
camera = PiCamera()

camera.start_preview()
frame = 1
while True:
  try:
    button.wait_for_press()
    camera.capture('/home/pi/Pictures/stopmotion/
frame%03d.jpg' % frame)
    frame += 1
  except KeyboardInterrupt:
    camera.stop_preview()
    break
```

» This script uses the PiCamera, sleep, and Button programs, from the picamera, time, and gpiozero libraries. It defines a button (pin 17) and camera, and waits for a button press.

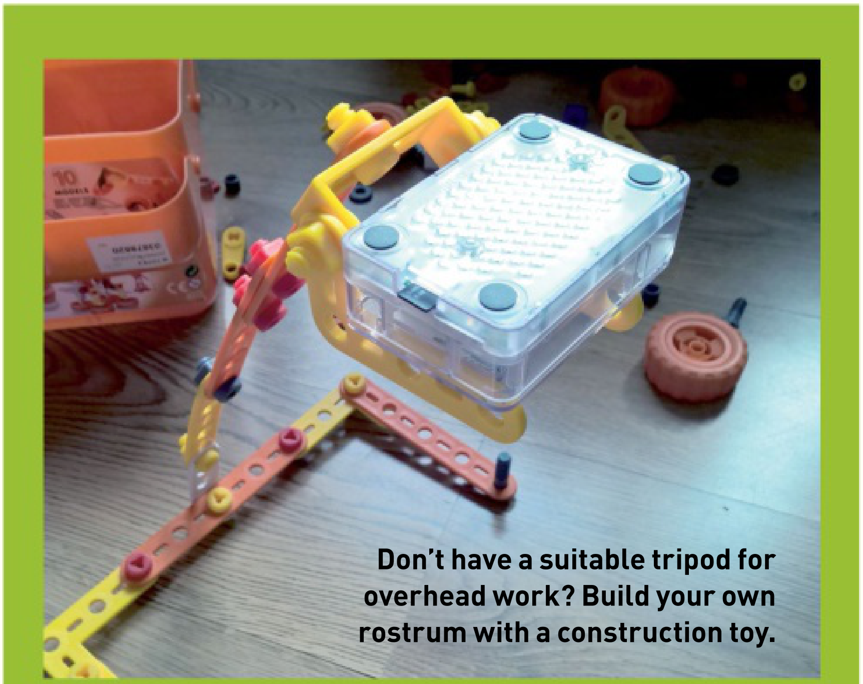
» At this point, it adds a single image into the specified directory. The script ends only when a keyboard interrupt command is detected.

4

ACTION!

With everything set up, it's time to make your movie. This could be considered as the difficult stage, depending on how much planning you've done (you have made a storyboard, haven't you?).

» In truth, however, if the Raspberry Pi is securely positioned, with a reliable power supply, and the shutter button correctly connected, you shouldn't have any trouble. The worst that's



Don't have a suitable tripod for overhead work? Build your own rostrum with a construction toy.

KEEP STEADY AND CARRY ON

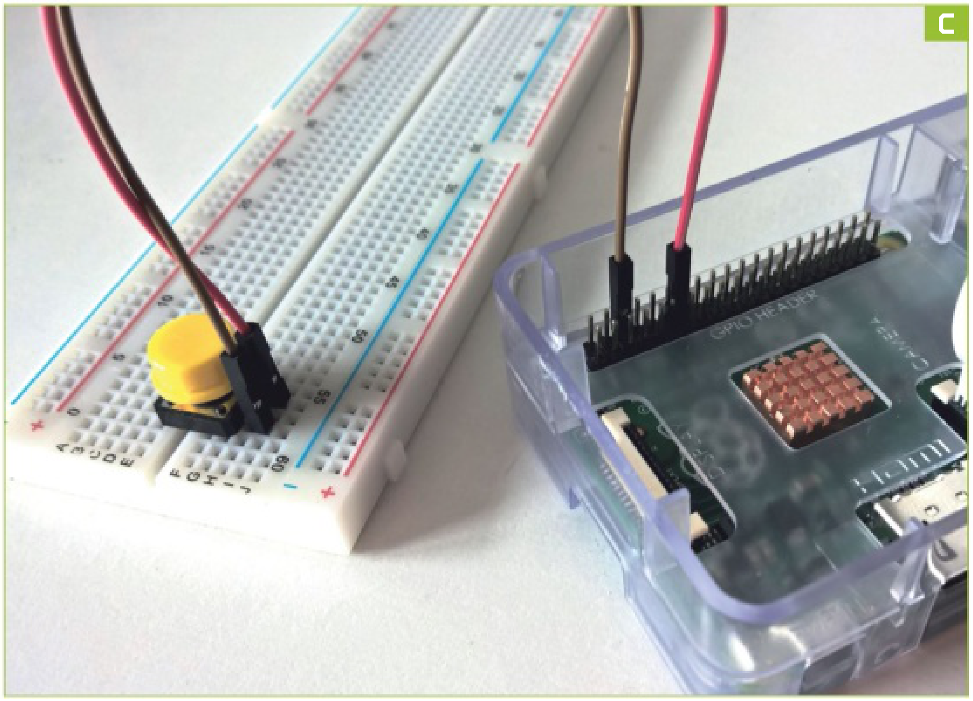
One important element to keep in mind is stability: It's all too easy to knock a camera, especially one mounted on a tripod. An overhead camera can also be subject to vibrations and wobbles.

The result of these bumps can be a jarring distortion in your finished movie. While repeating the shot is one solution, it can be time-consuming to arrange. A better solution is to ensure that the camera is secured to a sturdy piece of gear.

A tripod should have a heavy, reliable base with a low center of gravity to avoid topples. An overhead camera should be securely connected to the base, or whatever rigging is being used to support it. You also need to minimize any vibrations that might occur during the capturing of your stop-motion frames. This can be difficult using the breadboard-based shutter button, so it's worth changing this to a direct GPIO pin connection with a long cable.

For this project, we opted to use a Raspberry Pi case with a mounting point for the Camera module. This meant we could use the Pi itself like a camera, positioning it using a smartphone tripod. You might opt to connect the Pi to a car-windshield-mounted smartphone holder for similar vibration-free stop-motion video.

For the best results, use a smartphone tripod to mount your Pi for improved stability in your stop-motion movie.



going to happen is probably a bit of back or neck ache as you make those small adjustments to your characters.

» Your recording of the movie should follow this simple procedure: Set up scene → take shot → move character/object(s) → take shot → move character/object(s) → take shot. This should continue until your movie is complete, or you're ready to take a break.

» Because every image is saved into the same folder with an individual file name, stopping and then restarting the following day should not be a problem. Nothing is likely to be overwritten, for example.

» When you're ready to stop recording the movie, press Ctrl-C on your Pi's keyboard. This terminates the stopmotion.py program and closes the preview. With the movie complete, it's time to compile those hundreds or thousands of individual images into a single movie file. Before you do that, however, it's a good opportunity to look for any images that didn't quite work out.

» For example, if you took multiple attempts at a particular shot, you can delete the ones you don't want (or move them to another directory). It's also a good chance to get a look at the overall movie in a sort of "filmstrip" view. This reveals whether the lighting is consistent, for example, or if your camera has drifted or been obviously knocked when shooting. In some cases, it might be possible to retake a shot if it is particularly poor. However, it may be easier to simply drop the image, and hope for the best.

» When you're ready to compile the images, browse to the "/stopmotion" directory within the terminal (or press F4 from within the desktop file manager to open a terminal). Then run:

```
avconv -r 15 -i stopmotion/frame%03d.jpg -qscale 2
animation.h264
```

» Wait while the process completes. Keep in mind the relatively low specification of your Raspberry Pi, and the fact that it is essentially creating a movie in high definition. This may take a while, so go and recover—maybe have a good shoulder rub.

» The completed file "animation.h264" can be run in your preferred media player. For instance, to play in the Raspberry Pi's omxplayer, use

```
omxplayer animation.h264
```

» Find the video is a bit jerky? Then try altering the frame rate and recompiling it, represented in the `avconv` command with the `-r 15` value. The higher the figure, the smoother the animation. Note that the animation also becomes shorter as you increase the frame rate.

5 SHARING WITH THE WORLD

With your movie completed, you may want to "um" and "ahh" over the problems. Or you might prefer to just get it out there to find out what people think of it.

» Pretty much anywhere to which you can currently upload movies is suitable. Better still, as the movie is probably only a few seconds long, it won't take long to upload—so you can think about uploading the stop-motion movie to YouTube, Facebook, Twitter, and so on.

» Alternatively, you could upload it to your preferred cloud storage account. From here, it should be easy to access it from your mobile device, then upload the file to Instagram, say.

6 AUDIO!

One shortcoming that you will have noticed with the creation of a stop-motion movie is the lack of sound. You have two main options to get around this.

» The first is to load up a desktop video-editing suite on your main PC (your Raspberry Pi probably isn't up to it!). Import the stop-motion video and add a soundtrack. This might be audio you already have saved to your PC, whether that's music or sound effects. Alternatively, you could record some custom sound effects or dialogue to accompany the action.

» However, there is also the option to add audio when you upload the video to YouTube. The Creator Studio enables you to add sounds from YouTube's library of royalty-free songs. The selection is pleasingly vast, so choose carefully!

ANOTHER PI TUTORIAL NEXT MONTH

LIGHTING BALANCE

Shadows can ruin even the best stop-motion animations, yet this problem can be easily avoided with a bit of forward planning. Lighting is the secret, but you need to avoid relying on daylight or a standard ceiling light. This needn't cause you to break the bank, either; small LED lights perfect for this can be bought for just a few dollars.

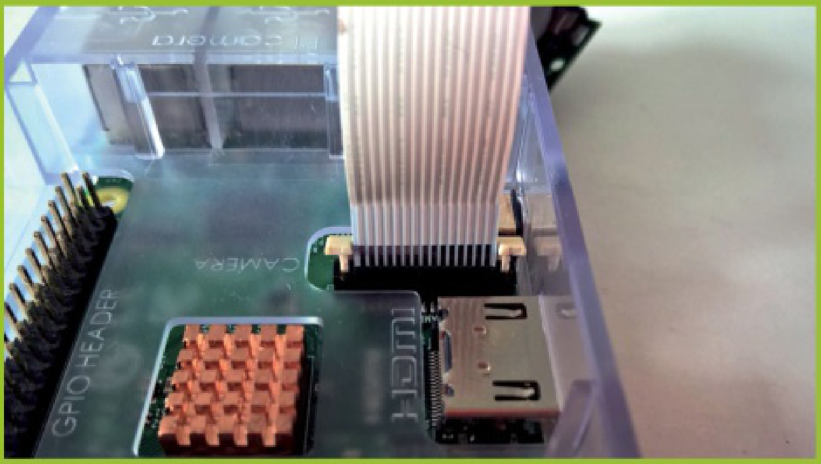
Positioning the lights to the left and right of the animation "stage" enables you to cancel out any shadows cast by you or the camera. If you're animating with objects, toys, or modeling clay, a third light from above also helps to cancel out shadows.

With the shadows banished, you should also ensure the white balance is set correctly. If you're using the recommended PiCamera software, auto white balance will probably work.

You can adjust this yourself by altering the `awb_mode` property, which by default is set to `awb_mode=auto`. Alternatives include `sunlight` and `cloudy`, though `tungsten`, `fluorescent`, and `incandescent` are set for typical indoor lighting temperatures.

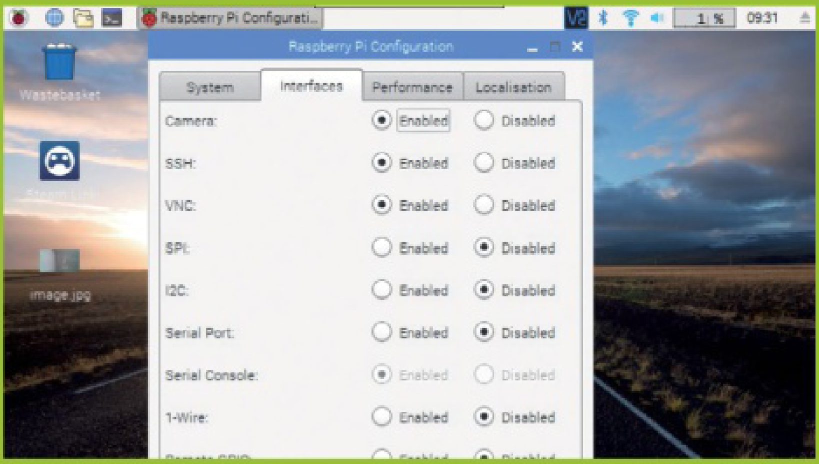
Meanwhile, you can even go as far as to disable `awb_mode` with the `off` setting. You can then specify a precise `awb_gains` setting (between 0.9 and 1.9). Consistent lighting results in a better stop-motion movie, so take the time to set this up accurately.

TURN YOUR RASPBERRY PI INTO A STOP-MOTION MOVIE STUDIO



1. CONNECT THE CAMERA MODULE

Hooking up the Camera module requires the correct cable for your Raspberry Pi computer. For Model A and B boards, the standard cable that ships with the Camera module is adequate. However, for the Pi Zero, a narrower cable is needed. Slot the cable into the port with the shiny side facing away from the Ethernet port (or facing up on the Pi Zero).



Camera: ● Enabled ○ Disabled
SSH: ● Enabled ○ Disabled
VNC: ● Enabled ○ Disabled
SPI: ○ Enabled ● Disabled
I2C: ○ Enabled ● Disabled
Serial Port: ○ Enabled ● Disabled
Serial Console: ● Enabled ○ Disabled
1-Wire: ○ Enabled ● Disabled

2. ENABLE THE CAMERA MODULE

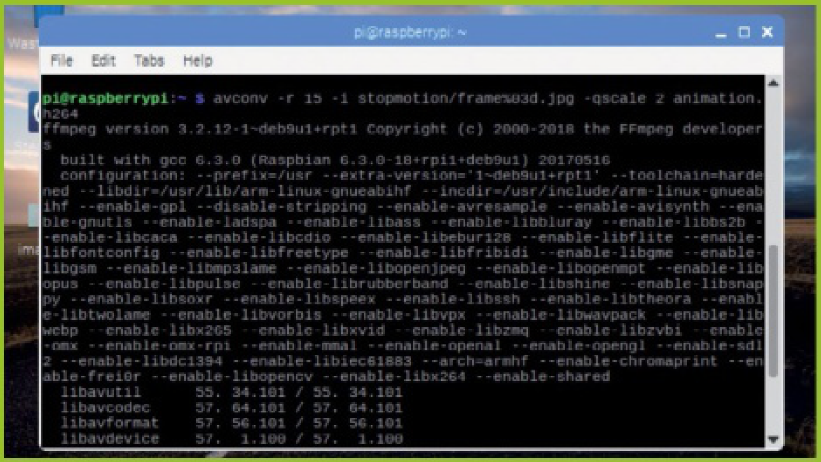
When you boot your Pi, you need to enable the camera. On the desktop, do this via "Menu → Preferences → Raspberry Pi Configuration." Select "Interfaces," then select the "Enabled" button for the camera, then click "OK." Alternatively, open a terminal and use the raspi-config app. Select "Interfacing Options," then "Camera." Choose "Enable," then "OK." Restart.

3. CONNECT A SHUTTER BUTTON

The complicated part of this project isn't all that tough, really. If you want to use the PiCam script, you need a shutter—an on-off (dual-state) plunger button connected to the Raspberry Pi at pins 6 and 11. Once connected to the GPIO, and with the script running, the button takes a single shot from the camera on each press.

4. START SHOOTING FRAMES

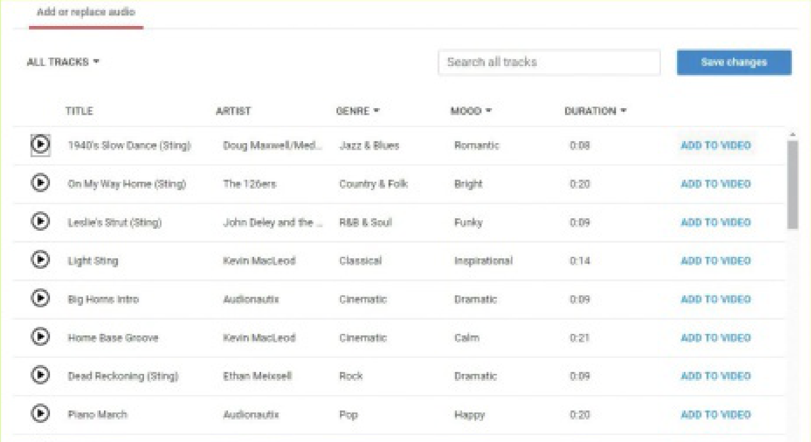
It's one thing to just plunge the button to make your movie, another to get the shots right. With the camera securely placed, and the characters and background in place, begin the tiring job of taking shot after shot to build the scene. Find safe shortcuts. Repeat shots wherever possible, and use as few characters, props, and other elements as possible.



```
pi@raspberrypi:~ $ avconv -r 15 -i stopmotion/frame%03d.jpg -qscale 2 animation.
h264
ffmpeg version 3.2.12-1~deb9u1+rpt1 Copyright (c) 2000-2018 the FFmpeg developer
s
  built with gcc 6.3.0 (Raspbian 6.3.0-18+rpi1+deb9u1) 20170516
  configuration: --prefix=/usr --extra-version='1~deb9u1+rpt1' --toolchain=harde
ned --libdir=/usr/lib/arm-linux-gnueabihf --incdir=/usr/include/arm-linux-gnueab
ihf --enable-gpl --disable-stripping --enable-avresample --enable-avisynth --ena
ble-gnutls --enable-ladspa --enable-libass --enable-libbluray --enable-libbs2b -
-enable-libcaca --enable-libcdio --enable-libebur128 --enable-libflite --enable-
libfontconfig --enable-libfreetype --enable-libfribidi --enable-libgme --enable-
libgsm --enable-libmp3lame --enable-libopenjpeg --enable-libopenmpt --enable-lib
opus --enable-libpulse --enable-librubberband --enable-libshine --enable-libsnap
py --enable-libsoxr --enable-libspeex --enable-libssh --enable-libtheora --enabl
e-libtwolame --enable-libvorbis --enable-libvpx --enable-libwavpack --enable-lib
webp --enable-libx265 --enable-libxvid --enable-libzmq --enable-libzvbi --enable
-omx --enable-omx-rpi --enable-mmal --enable-openal --enable-opengl --enable-sdl
2 --enable-libdc1394 --enable-libiec61883 --arch=armhf --enable-chromaprint --en
able-frei0r --enable-libopencv --enable-libx264 --enable-shared
  libavutil      55. 34.101 / 55. 34.101
  libavcodec     57. 64.101 / 57. 64.101
  libavformat    57. 56.101 / 57. 56.101
  libavdevice    57.  1.100 / 57.  1.100
```

5. CREATE A MOVIE WITH AVCONV

The completed movie appears as a collection of stills in the destination folder. A flick-book effect can be enjoyed by scrolling through the photos in your file manager's preview panel. Using avconv to convert the photos into a movie is simple, but time-consuming for longer projects. Be sure to set the right FPS to get the best results first time.



TITLE	ARTIST	GENRE	MOOD	DURATION	
1940's Slow Dance (Sting)	Doug Maxwell/Med...	Jazz & Blues	Romantic	0:08	ADD TO VIDEO
On My Way Home (Sting)	The 126ers	Country & Folk	Bright	0:20	ADD TO VIDEO
Leslie's Strut (Sting)	John Deley and the ...	R&B & Soul	Funky	0:09	ADD TO VIDEO
Light Sting	Kevin MacLeod	Classical	Inspirational	0:14	ADD TO VIDEO
Big Horns Intro	Audionautix	Cinematic	Dramatic	0:09	ADD TO VIDEO
Home Base Groove	Kevin MacLeod	Cinematic	Calm	0:21	ADD TO VIDEO
Dead Reckoning (Sting)	Ethan Meixsell	Rock	Dramatic	0:09	ADD TO VIDEO
Piano March	Audionautix	Pop	Happy	0:20	ADD TO VIDEO

6. ADD AUDIO WITH YOUTUBE

Stop-motion animation is sound-free by default. While it might be fun to let the movie play out in total silence, you have a few options to add sound. One is to load the finished video into a movie-editing app and add some custom audio with a mic. The other is to add music to the audio in YouTube when you upload it, using its Creator Studio.

Superior Screenshots with ShareX

YOU'LL NEED THIS

SHAREX
Download this open-source tool from https://getsharex.com.

WHILE THE WINDOWS OPERATING SYSTEM has built-in tools for taking screenshots, they're somewhat limited. For instance, there's no quick and easy way to alter the image format and quality, nor automate screenshots by taking them at regular intervals. Fortunately, the free and open-source utility ShareX serves as a one-stop store for all your screenshot needs. The program can mimic Windows' built-in screen capture utility, but can also capture specific areas of your desktop in high-quality image and video formats. You can access these features via ShareX's intuitive drop-down menu or by mapping your own quick and easy hotkeys.

If you ever find yourself writing a tutorial or walkthrough, the ShareX image editor contains a very satisfactory toolset to highlight and annotate important sections. And in the tutorial you're reading right now, you'll discover how to download and set up ShareX, take basic and advanced screenshots, map hotkeys, take screenshots at fixed intervals, and even edit images, without costing you a dime.

Although this guide helps you to master the basics, it only scratches the surface of the dozens of features available in ShareX. If you want to explore these further, consider visiting the documentation of the ShareX website at https://getsharex.com/docs/faq. –**NATE DRAKE**

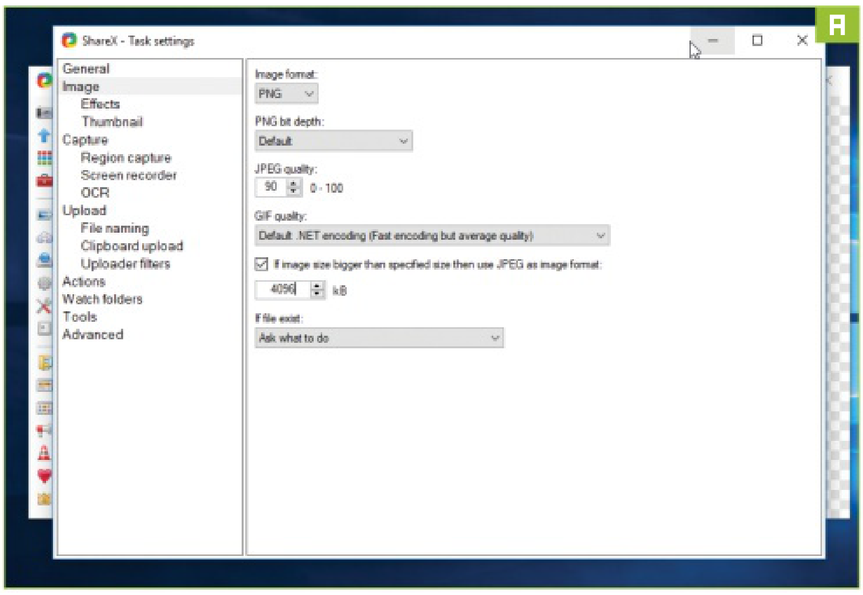

A
ShareX - Task settings
General
Image
Effects
Thumbnail
Capture
Region capture
Screen recorder
OCR
Upload
File naming
Clipboard upload
Uploader filters
Actions
Watch folders
Tools
Advanced

Image format: PNG
PNG bit depth: Default
JPEG quality: 90 0 - 100
GIF quality: Default .NET encoding (Fast encoding but average quality)
☑ If image size bigger than specified size then use JPEG as image format:
4096 kB
If file exist: Ask what to do

1 DOWNLOAD AND INSTALL SHAREX

Open your web browser and navigate to https://getsharex.com. Click the button marked "Download." The installer is only around 5.5MB. Once it's downloaded, double-click to run. At this point, Windows 10 asks you to confirm before proceeding. Click the radio button to accept the license agreement, then choose "Next." Confirm your install destination folder and click "Next" to continue. Select "Next," then "Install" to finalize installation and add a desktop shortcut.

2 CAPTURE YOUR FIRST SCREENSHOT

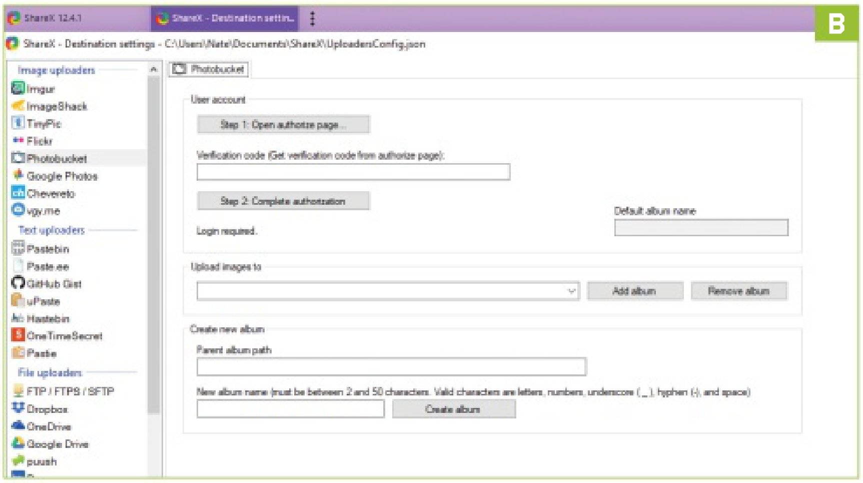
ShareX contains a huge number of screenshot tools. To take a basic screenshot, first launch the program by double-clicking the desktop shortcut. Next, open the drop-down menu at the top-left of the screen. For now, choose "Fullscreen." ShareX plays a shutter sound to confirm the screenshot has been captured. The program also asks you if you wish to upload the image. For the time being, click "No." ShareX displays a thumbnail of the most recently captured screenshot at the bottom-right of the window. Double-click the thumbnail to open the image in File Explorer. By default, screenshots are stored in C:\ Users\Yourusername\ Documents\ShareX.

3 ADVANCED SCREENSHOTS

When you clicked the drop-down menu, you may have noticed that there are many alternatives to capturing the entire screen. Choose "Window" to capture an image of an active window. Once clicked, ShareX displays a list of open windows. Click your desired window to take the picture. Use "Monitor" to take screenshots of any external screens you've connected. Secondary monitors appear in a drop-down menu. You can use "Region" to capture a specific area of the screen; click and drag over your desired area, then release the left mouse button to capture the image. If you need to take multiple images of the same area of the screen, choose "Last Region." This saves a screenshot of the previous region you selected each time you click it.

4 CONFIGURE CAPTURE QUALITY

By default, ShareX stores screenshots in PNG format, unless in so doing they'd be greater than 2MB, in which case images are saved in JPEG format. You can change image quality settings by clicking the "Task Settings" button on the left, then "Image" [**Image A**]. Select a new "Image format," such as JPEG, from the drop-down menu. From here you can also set JPEG image quality between 0 and 100. To change the

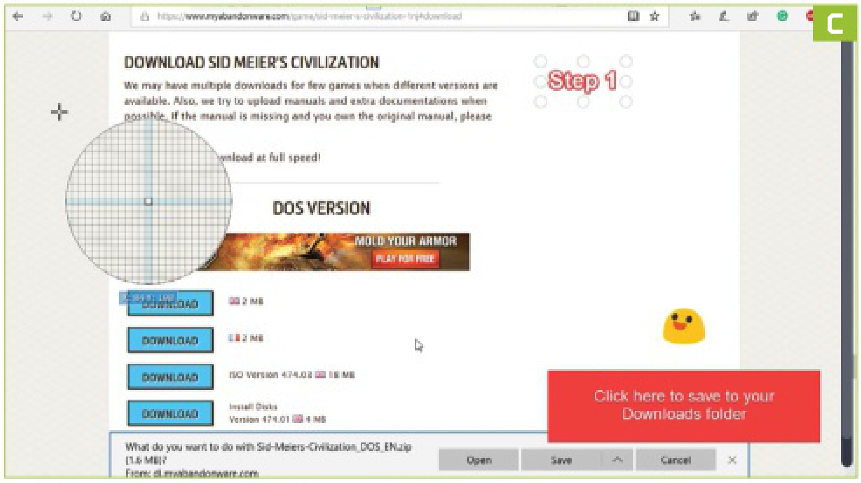

B
ShareX 12.4.1
ShareX - Destination settin...
Image uploaders
Imgur
ImageShack
TinyPic
Flickr
Photobucket
Google Photos
Chevereto
vgy.me
Text uploaders
Pastebin
Paste.ee
GitHub Gist
uPaste
Hastebin
OneTimeSecret
Pastie
File uploaders
FTP / FTPS / SFTP
Dropbox
OneDrive
Google Drive
puush
Photobucket
User account
Step 1: Open authorize page...
Step 2: Complete authorization
Default album name
Upload images to
Add album
Remove album
Create new album
Parent album path
Create album

ShareX - Destination settings - C:\Users\Nate\Documents\ShareX\UploadersConfig.json

Verification code (Get verification code from authorize page):

Login required.

New album name (must be between 2 and 50 characters. Valid characters are letters, numbers, underscore (_), hyphen (-), and space)



https://www.myabandonware.com/game/sid-meier-s-civilization-1nj#download

DOWNLOAD SID MEIER'S CIVILIZATION

We may have multiple downloads for few games when different versions are available. Also, we try to upload manuals and extra documentations when possible. If the manual is missing and you own the original manual, please

wnload at full speed!

DOS VERSION

2 MB

2 MB

ISO Version 474.03 18 MB

Install Disks Version 474.01 4 MB

What do you want to do with Sid-Meiers-Civilization_DOS_EN.zip (1.6 MB)?
From: dl.myabandonware.com

Click here to save to your Downloads folder

maximum file size after which JPEG is used, change the stated value from 2048 to a larger one—4096, for example.

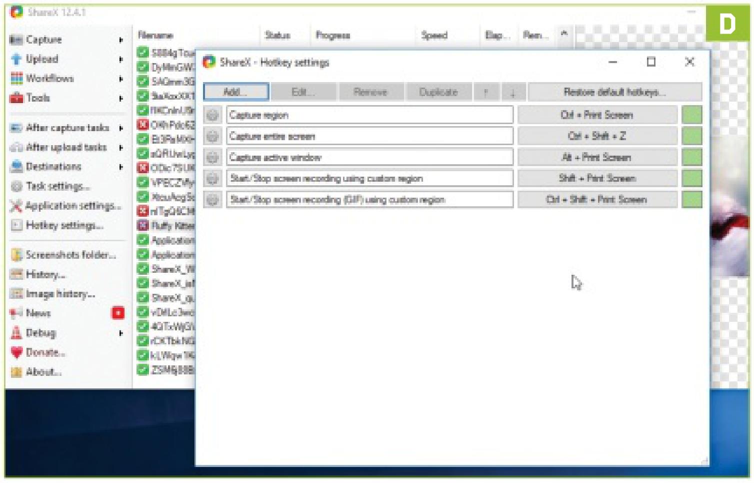
›› ShareX also supports video capture of your desktop. You can change settings for this by going to “Task Settings,” then “Screen Recorder.” By default, the program uses AAC for audio and MP4 for video. You can change the “Video codec” via the drop-down menu. ShareX also supports AVI and GIF. Feel free to change the “Audio Codec” in the same way.

5 UPLOAD SCREENSHOTS

The easiest way to back up and share your screenshots is to upload them automatically to an image-sharing website, such as Imgur. If you chose not to do this when setting up ShareX, but have changed your mind, click “After capture task” on the left-hand side of the screen. Next, click to enable “Upload images to host,” then select the button marked “Destinations.” From here, you can choose an image host [**Image B**]. If you select a host requiring registration, such as Photobucket, ShareX opens a pop-up window enabling you to sign in. From now on, when you take a screenshot it is automatically uploaded. Double-click ShareX image thumbnails to open them in your browser. Alternatively, right-click a thumbnail, and choose “Copy → URL” to save the image link to your clipboard. This works for other images, too. Simply drag any picture into the ShareX window to upload it to the host.

6 EDIT SCREENSHOTS

If you’re writing a guide, you may want to edit your screenshots to highlight a particular section, add a caption, and so on. To get started, open the “Tools” menu, then choose “Image Editor.” Alternatively, right-click a screenshot thumbnail and select “Edit Image.” The image-editing tools are displayed in a bar along the top of the window, and are very similar to those available in Microsoft Paint. Use the hand emoji tool to indicate where to click or enter text. The ShareX image editor also contains a very useful Speech Bubble tool for annotating areas of the screen. If you insert any text into the image, consider using the Border tool to highlight it in a colorful and striking way [**Image C**]. By default, any changes you make are saved over the original image. However, you can click the “Save As” button at the top-left to store a new version.



ShareX - Hotkey settings

Capture region — Ctrl + Print Screen
Capture entire screen — Ctrl + Shift + Z
Capture active window — Alt + Print Screen
Start/Stop screen recording using custom region — Shift + Print Screen
Start/Stop screen recording (GIF) using custom region — Ctrl + Shift + Print Screen

7 USE HOTKEYS

ShareX has a number of built-in hotkeys, enabling you to effortlessly capture screenshots. For instance, press the “Print Screen” button while ShareX is running to capture a screenshot of your entire desktop. Other hotkey options include capturing an active window (Alt-Print Screen) and capturing a region (Ctrl-Print Screen). You can view a full list of hotkey options by clicking the “Hotkey Settings” button on the left-hand side of the screen.

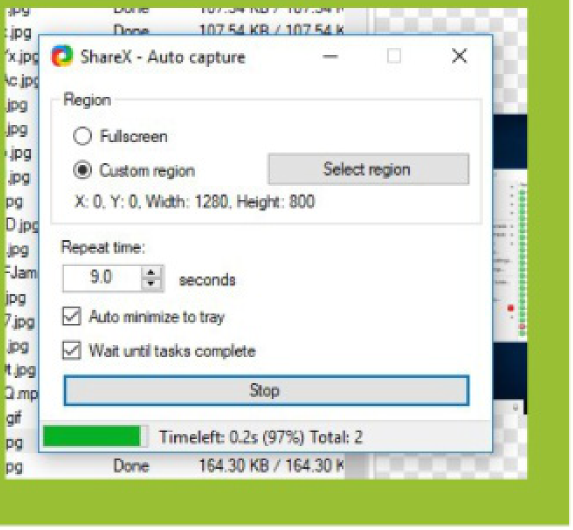
›› From here, you can also reconfigure your hotkey settings. For instance, to change the shortcut for taking a screenshot of the entire screen, click “Print Screen hotkey” next to “Capture Entire Screen.” Next, hold down your new hotkey combination, such as Ctrl-Shift-Z.

›› You can also map hotkeys to other functions by selecting “Add” [**Image D**], then clicking the settings icon beside the new hotkey box below. From here, choose “Task” and click the task you want configured to your hotkey—“Upload File,” for instance. Enter your hotkey combination in the blank box next to the description. ⏻

AUTO CAPTURE

ShareX can be programmed to use Auto Capture, meaning it takes a screenshot at periodic intervals—every 30 seconds, for instance. This can be useful if you’re actively using a program, such as a video game, so can’t stop every few seconds to take pictures of your progress. The Auto Capture feature can also record screenshots of ShareX itself, in case you want to share its features with other PC users.

To get started with Auto Capture, click the “Capture” button on the left-hand side of the screen. Scroll down to “Auto Capture.” Click this to open the settings. From here, you can choose to auto capture either the full screen or a specified area of the desktop. Use “Repeat time” to alter the interval at which screenshots are automatically captured. When you’re ready, click “Start” to begin auto capture. Screenshots are saved in the default ShareX folder in My Documents. Minimize the ShareX window before continuing. Once you have captured all the screenshots you need, restore the ShareX window, and click “Stop.”



ShareX - Auto capture

○ Fullscreen
● Custom region
X: 0, Y: 0, Width: 1280, Height: 800

Repeat time: 9.0 seconds

☑ Auto minimize to tray
☑ Wait until tasks complete

Timeleft: 0.2s (97%) Total: 2

Done 107.54 KB / 107.54 K
Done 164.30 KB / 164.30 K

Search in Style with Wox

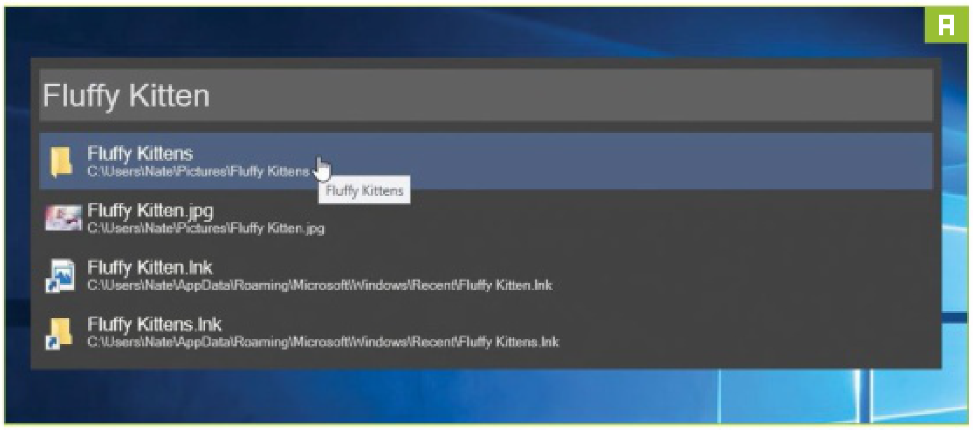
YOU'LL NEED THIS

WOX
Find out more at www.wox.one, then follow a link to download the app.

LOVERS OF A CERTAIN FRUITY BRAND of computers often cite the built-in "Spotlight" feature as one of their favorites. The deceptively simple search bar enables them to navigate every file, folder, and program on their system. The free and open-source utility Wox is an answer to the prayers of Windows users everywhere. On first launch, Wox displays its handy search bar, which you can use to display locations and applications effortlessly. You can also expand Wox's features via downloadable plugins, which include Google searches, translation, and a powerful calculator, to name just a few.

In this guide, you'll learn how to hit the ground running with Wox. The easy setup process means you'll be running your first search within minutes. You'll then discover how to list Google search results and other features. Wox is configured to support programmable "hotkeys." This enables you to launch your favorite files, websites, and programs with a few quick key presses.

The only real criticism of Wox is that the default settings are quite intrusive, because it appears right in the center of your screen. Luckily, the built-in settings support hiding Wox while not in use, as well as moving the search bar to a more discreet location. **–NATE DRAKE**



A

```
Fluffy Kitten
Fluffy Kittens
C:\Users\Nate\Pictures\Fluffy Kittens
Fluffy Kittens
Fluffy Kitten.jpg
C:\Users\Nate\Pictures\Fluffy Kitten.jpg
Fluffy Kitten.lnk
C:\Users\Nate\AppData\Roaming\Microsoft\Windows\Recent\Fluffy Kitten.lnk
Fluffy Kittens.lnk
C:\Users\Nate\AppData\Roaming\Microsoft\Windows\Recent\Fluffy Kittens.lnk
```

1 INSTALL WOX

Open your browser of choice and go to www.wox.one. Although you can't download Wox directly from the main site, you can take some time to explore its features before installing. When you're ready, click "Download" to be redirected to the Wox project GitHub page. Scroll down and find the EXE file—"Wox -1.3.578," for instance. Choose to run the installer. Once the install is complete, Wox automatically creates a desktop shortcut, and the search bar appears in the center of your screen.

2 SEARCH FOR FILES AND PROGRAMS

By default, the Wox search bar readily indexes and displays any files, folders, and programs stored on your system. To get started, in the search bar, enter the name of a file or folder you've previously created—for instance, "Fluffy Kitten"—and Wox reveals the file. Press Enter to automatically open the target file. This also works for applications: Simply type the name of your chosen program, such as "Paint," and press the Return key. If your search displays multiple results [**Image A**], you can navigate these using the arrow keys. Use Enter or click once to launch.

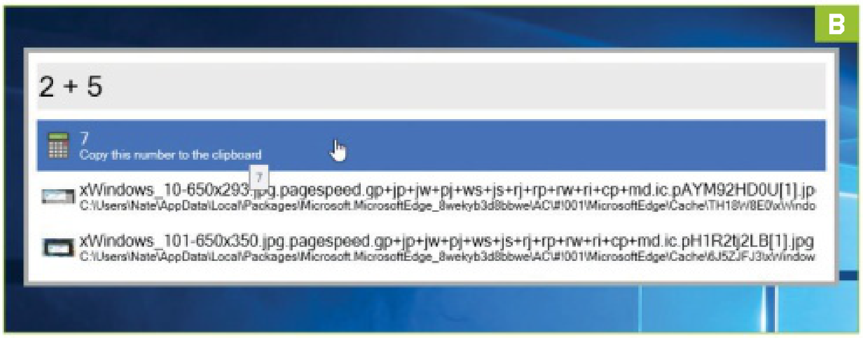
3 ENABLE WEB SEARCHES

Wox supports a number of plugins, which you can use to add extra features. The Web Searches plugin displays Google results for any terms you enter into the Wox search bar. To get started, open Wox, and type the following: `wpm install Web Searches`. Wox asks you to confirm you want to activate this plugin. Click "Yes" to continue. Next, close and re-open Wox. (You can do this either via the desktop shortcut or by holding Alt-Space). From now on, each time you enter a search term, Wox lists the top Google search results.

» The Web Searches plugin also supports "Action Keywords." These enable you to enter just a few letters—for example, "CNN" might take you to http://edition.cnn.com. To get started, right-click the Wox icon in the system tray at the bottom of your screen. Choose "Settings." Once the Settings window launches, click the "Plugins" tab. Scroll down to "Web Searches" on the left-hand side. Click to highlight this, then select the "Add" button on the bottom-right. Enter a name for your URL shortcut, such as "CNN." Under "URL," enter the target web address, then enter your chosen keyword under "Action Keyword." Click "Add" again to save your settings. Links open in your system's default browser.

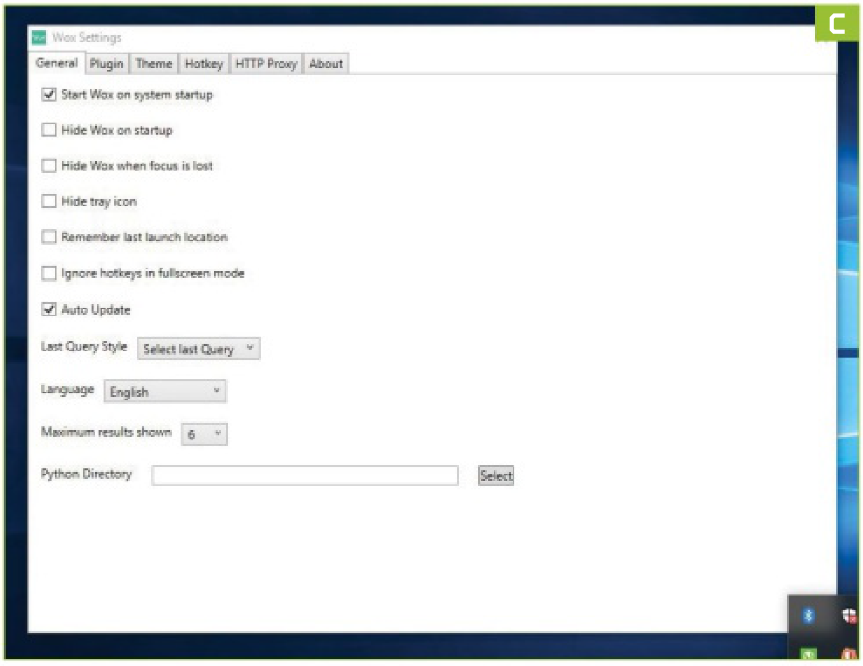
4 ENABLE SYSTEM COMMANDS

Although Wox can run commands in the same way as CMD.EXE, this is usually overkill for most users. Fortunately, Wox has a built-in plugin called System Commands that is suitable for most applications. To get started, open the Wox search bar, and type: `wpm install System Commands`. Wox again asks you if you are sure you want to install this plugin. Click "Yes." Close and relaunch Wox, then head to the "Plugins" tab as outlined in the previous step. Click to highlight



B

```
2 + 5
7
Copy this number to the clipboard
7
xWindows_10-650x293.jpg.pagespeed.gp+jp+jw+pj+ws+js+rj+rp+rw+ri+cp+md.ic.pAYM92HD0U[1].jp
C:\Users\Nate\AppData\Local\Packages\Microsoft.MicrosoftEdge_8wekyb3d8bbwe\AC\#!001\MicrosoftEdge\Cache\TH18W8E0\xWindo
xWindows_101-650x350.jpg.pagespeed.gp+jp+jw+pj+ws+js+rj+rp+rw+ri+cp+md.ic.pH1R2tj2LB[1].jpg
C:\Users\Nate\AppData\Local\Packages\Microsoft.MicrosoftEdge_8wekyb3d8bbwe\AC\#!001\MicrosoftEdge\Cache\6J5ZJFJ3\xWindow
```



☑ Start Wox on system startup
☐ Hide Wox on startup
☐ Hide Wox when focus is lost
☐ Hide tray icon
☐ Remember last launch location
☐ Ignore hotkeys in fullscreen mode
☑ Auto Update
Last Query Style: Select last Query
Language: English
Maximum results shown: 6
Python Directory:

"System Commands" on the left-hand side of the window. This displays the various commands you can run. The commands are very straightforward, such as "Shutdown" and "Sleep." The "Restart Wox" command may come in handy if you want to install more plugins.

5 ENABLE ADDITIONAL PLUGINS

If you followed the instructions in the previous step, you may have seen that there's a number of additional plugins listed besides Web Searches. Click the "Browse more Plugins" button from the "Plugins" tab to view the database from the Wox website. Each plugin page displays the code you need to enter in the Wox search bar to install the relevant plugin—for example, `wpm install Python Calculator`. Wox then asks you to confirm the install. Click "Yes" to proceed. Wox needs to restart to activate the plugin.

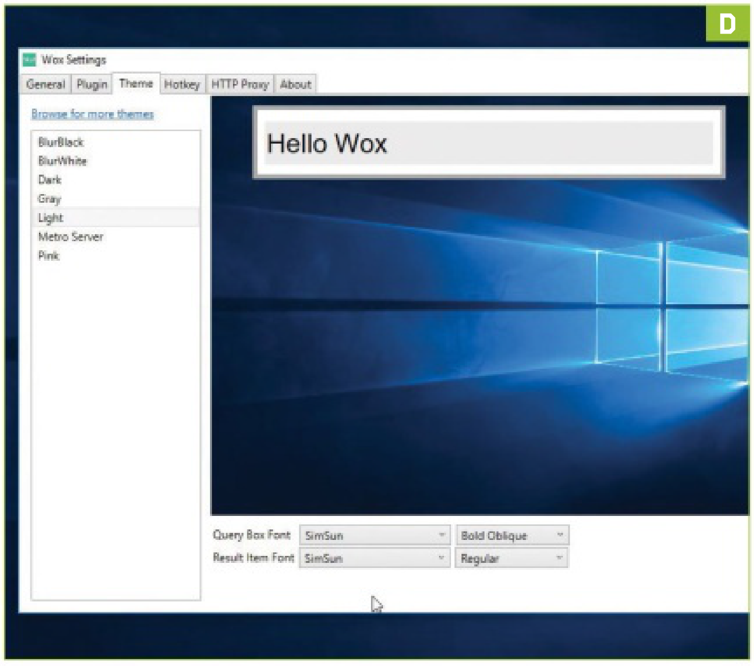
›› If you install the Calculator plugin [**Image B**], you can carry out calculations in the navigation bar itself. The Shell plugin allows you to type "Shell" commands in the search bar, and you can even replace Win-R. If none of the plugins are to your liking, you can code your own. Wox supports C#, Python, Node.js, and Golang, among others.

6 TWEAK WOX SETTINGS

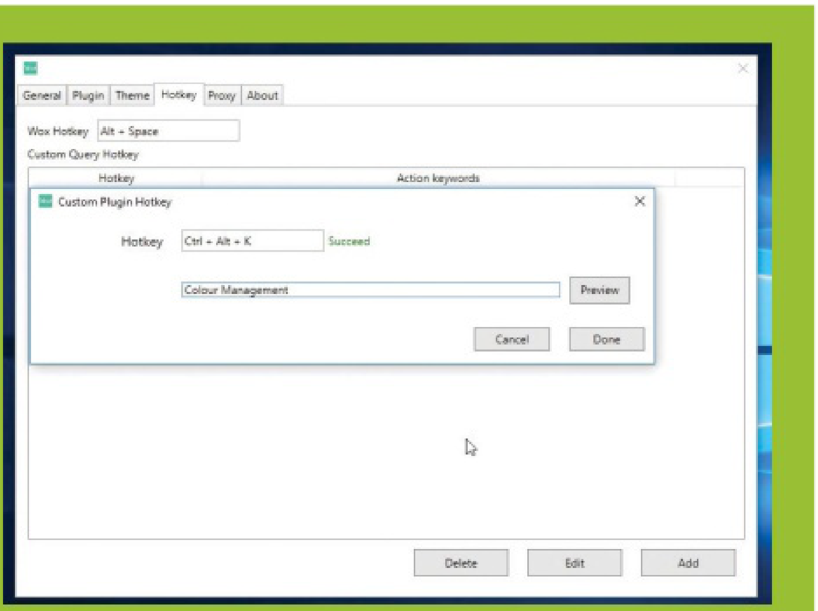
You can access the Wox settings either by the system tray as outlined above, or by typing "Settings" into the Wox search bar. Under the '"General" tab, you can toggle some of Wox's default options, such as "Start Wox on system startup" and "Auto Update" [**Image C**]. The Wox search bar superimposes itself over other windows upon launch, so you may want to enable "Hide Wox on startup." Alternatively, click "Hide Wox when focus is lost" to automatically dismiss the Wox search bar if you start doing something else, such as entering text on a webpage. If you want to move the Wox search bar permanently to a less prominent location, such as the top-left of your screen, choose "Remember last launch location" to store the bar's position between launches.

7 THEMES

By default, Wox uses a rather drab "Dark" theme. You can change this from the "Themes" tab [**Image D**]. There are seven pre-installed alternate themes. You can also choose to "Browse for more themes" on the Wox default. If you see a theme you like, click "Download," then "Save." Restart Wox and open the "Settings" menu. You can now select your new theme from the "Themes" tab. You can also change the font type and style of not only your Wox search query, but also the search results. The "Query" box and search result font automatically use Microsoft Sans Serif with regular typeface. You can change either of these at any time. The font for both has to be same, but you can set a different typeface if you wish. ⏻



Query Box Font: SimSun | Bold Oblique
Result Item Font: SimSun | Regular



Wox Hotkey: Alt + Space
Custom Query Hotkey
Hotkey: Ctrl + Alt + K Succeed
Colour Management

WOX HOTKEYS

The Wox search bar can also be accessed via a number of keyboard shortcuts. Some of these are built-in—for instance, you can launch Wox automatically by holding down Alt-Space. You can also configure new hotkeys to launch your favorite programs and files. To do this, first enter "Settings" in the Wox search bar, then press Enter. Click the "Hotkeys" tab. By default, the only assigned hotkey combination is the one that launches Wox. Click to highlight this with your mouse, then choose an alternate hotkey if you wish.

Click the "Add" button to start creating a new hotkey. This opens a new window. First, click the "Hotkey" box, then hold down your desired key combination—for example, Ctrl-Alt-K. Next, type the name of your chosen file, folder, or application, such as "Color Management," in the box below. Finally, click "Done" to save your new hotkey. If you no longer require a particular hotkey combo, simply revisit the "Hotkey" tab, highlight the redundant command with your mouse, and press the "Delete" button.

Clear Desktop Clutter with Groupy

YOU'LL NEED THIS

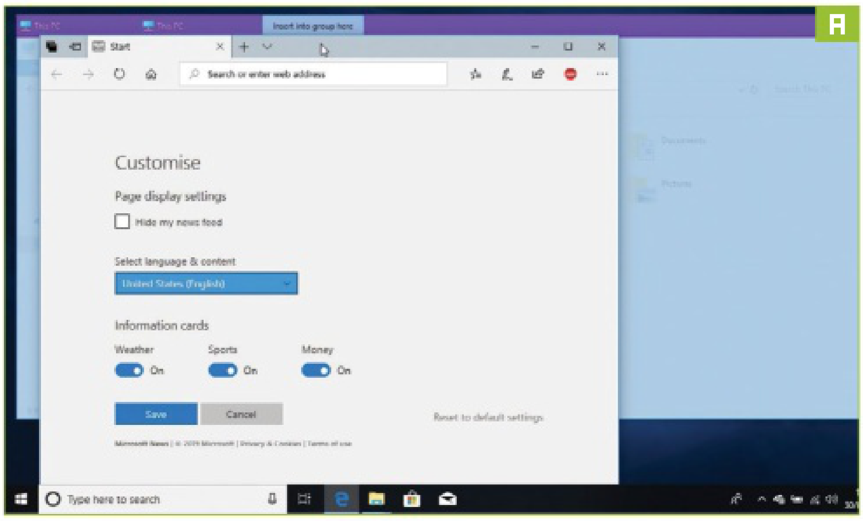
GROUPY
Download a free 30-day trial version from www.stardock.com/products/groupy, or pay $10 for the full app.

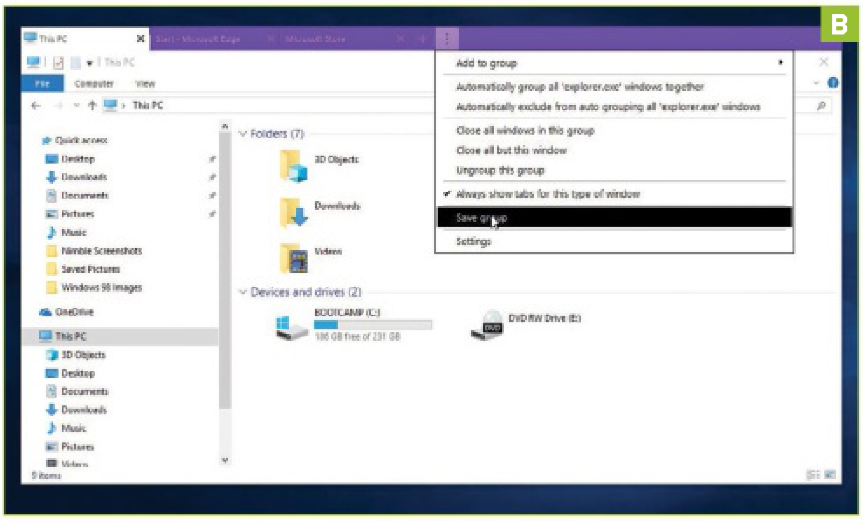
IF YOU'VE EVER HAD TO JUGGLE multiple work or study assignments at once, you may have come to resent the concertina of open windows on your desktop. Groupy is a free-to-try utility that attempts to declutter your desktop by organizing your files and programs into tabs. This idea is hardly new, as web browsers have happily displayed dozens of webpages side by side for years. However, Groupy borrows this concept and extends it, by applying it to other programs, such as File Explorer.

In this tutorial, you'll discover how to install Groupy and set up your first group of tabs. After taking some time to flick between these effortlessly, you'll also learn how to save and restore your favorite groups. Groupy can also change its appearance to some extent to make tabs easier to navigate, move, open, and close.

If, like us, you become a Groupy convert overnight, the program also supports automatically grouping together multiple instances of the same program, such as Microsoft Paint. And if you're worried about becoming too trigger-happy and tabbing everything in sight, Groupy also supports "Opt-in" tabulation using key presses.

Groupy is available as a 30-day free trial. If you feel your life is enriched by it, you'll need to pay $9.99 to obtain a product key for the full version. **–NATE DRAKE**


A
Insert into group here
Customise
Page display settings
Hide my news feed
Select language & content
United States (English)
Information cards
Weather
Sports
Money
On
Save
Cancel
Reset to default settings
Type here to search


B
This PC
Add to group
Automatically group all 'explorer.exe' windows together
Automatically exclude from auto grouping all 'explorer.exe' windows
Close all windows in this group
Close all but this window
Ungroup this group
Always show tabs for this type of window
Save group
Settings
Quick access
Folders (7)
Devices and drives (2)

1 DOWNLOAD AND INSTALL GROUPY

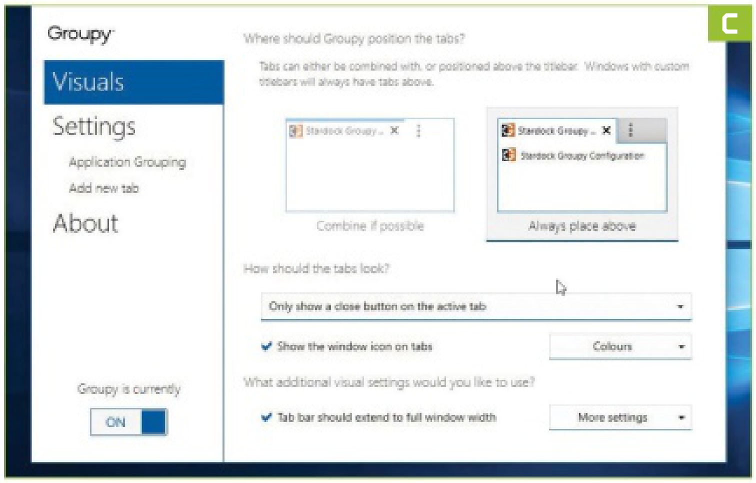
Open your web browser and navigate to www.stardock.com/products/groupy/. Click "Try it Free!" to download the installer for the trial version of Groupy. Double-click to launch the installer from your "Downloads" folder. Windows 10 users need to click "Yes" to allow the program to make changes. Select the radio button to agree to the licensing agreement, then click "Next." Confirm your install location, then click "Next" again. Once installation is complete, Groupy launches automatically. Groupy now asks you to enter a product key; instead, select "Start 30-day free trial," then enter your email address to receive an activation link. You must click the link to start using Groupy.

2 ADD YOUR FIRST APP TO A GROUPY TAB

On first launch, Groupy displays a "Welcome" screen giving more information about the utility and how to get started. Read this, then click "Close" on the bottom-right. From here, you can adjust Groupy's tab and visual settings. But for now, open a new File Explorer window. Next, add your program of choice by dragging the application window over the title bar in File Explorer. Release the mouse button and the tab is created automatically. Click each tab to switch between windows. Groupy is compatible with a number of applications beyond File Explorer, such as Microsoft Edge and Paint. Feel free to open these and add other windows as a new tab until you feel comfortable with the process [**Image A**].

3 ORGANIZE YOUR GROUPY TABS

Now you know how to add programs to new Groupy tabs and windows, open a few more of your essential programs and files. Next, drag them into a Groupy-compatible window, such as the File Explorer

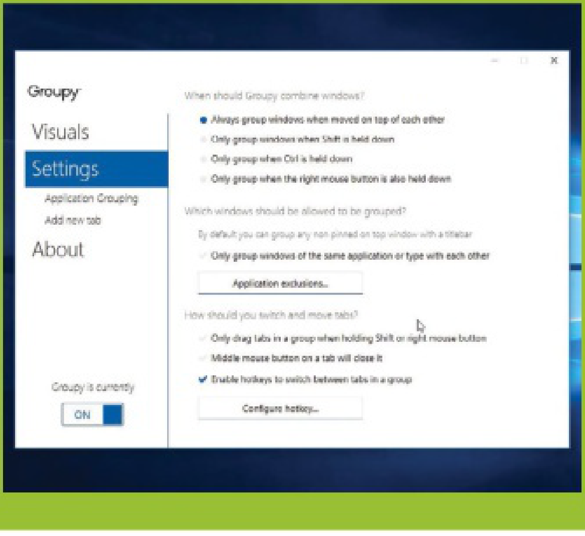

C
Groupy
Visuals
Settings
Application Grouping
Add new tab
About
Combine if possible
Always place above
Colours
More settings
Groupy is currently
ON

Where should Groupy position the tabs?
Tabs can either be combined with, or positioned above the titlebar. Windows with custom titlebars will always have tabs above.
How should the tabs look?
Only show a close button on the active tab
✓ Show the window icon on tabs
What additional visual settings would you like to use?
✓ Tab bar should extend to full window width

GROUPING WITH GROUPY

As helpful as it can be to cluster your favorite programs and files into tabs, you may prefer to keep certain apps in a dedicated window. If you're juggling with multiple programs, it's hard to avoid moving one window accidentally over another, and snapping them together. Mercifully, the developers of Groupy anticipated this, and have designed the utility with some tab-avoidance options. To get started, launch Groupy and find the "Settings" section in the main interface. Under "When should Groupy combine windows?" choose one of the four options listed, such as "Only group when Shift button is held down."

If, on the other hand, you're totally taken with Groupy, you can automatically combine tabs for various applications. Find the section marked "Application grouping" under "Settings," then work your way through the checkboxes. Select "Automatically group identical windows together unless in another group" to ensure that new files or programs you launch are automatically tabbed.


Groupy

Visuals

Settings

Application Grouping

Add new tab

About

When should Groupy combine windows?

● Always group windows when moved on top of each other

○ Only group windows when Shift is held down

○ Only group when Ctrl is held down

○ Only group when the right mouse button is also held down

Which windows should be allowed to be grouped?

By default you can group any non pinned on top window with a titlebar

☐ Only group windows of the same application or type with each other

Application exclusions...

How should you switch and move tabs?

☐ Only drag tabs in a group when holding Shift or right mouse button

☐ Middle mouse button on a tab will close it

☑ Enable hotkeys to switch between tabs in a group

Configure hotkeys...

Groupy is currently ON

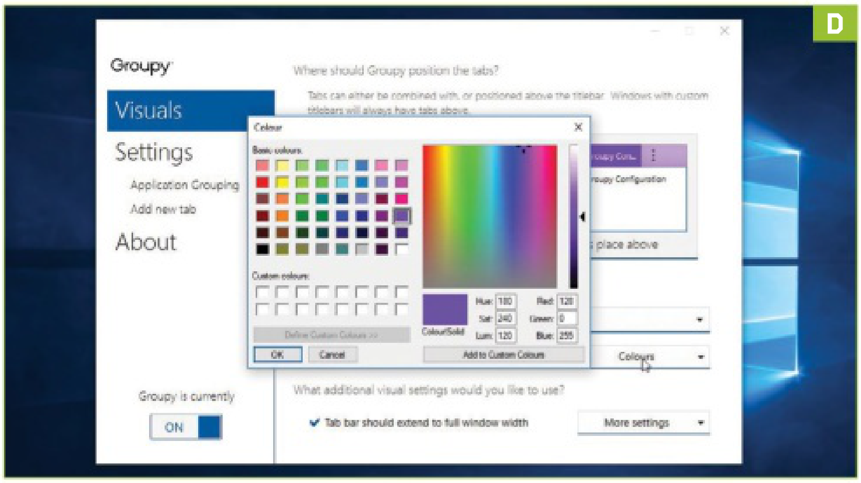
one you opened earlier in the same way. Re-order tabs by pressing and holding the left mouse button, then moving left and right. To close tabs, hover your mouse over the tab name, then click the "X" next to it. Alternatively, change tabs back to regular windows by dragging and dropping them on to the desktop. To close all tabs, click the "X" at the top-right, as you would for any normal window. If you have any unsaved work , the program still asks whether you want to save changes.

4 SAVE TABS AS A GROUP

By default, when you close a Groupy window or shut down your PC, any open tabs are lost. Fortunately, Groupy supports saving tabs as "Groups," so they can be restored. To get started, click the Groupy options button ("...") at the top-right of the window. Scroll down to "Save Group" [**Image B**]. Click this option to enter a group name—"Art Class Materials," for example. Select "Save" to finalize your changes. Groups are saved on a window by window basis, so if you have multiple Groupy windows open, you must save each one as a separate group.

5 LOADING AND EDITING GROUPS

You can restore groups at any time by clicking the options button at the top-right of any Groupy-compatible window, then scrolling down to "Saved Groups." Double-click the name of your saved group to restore all your tabs. Any new tabs you add to a group aren't automatically saved, but you can resave new tabs using the same group name by following the instructions in step 6. If you're managing multiple groups, you can also search for them in the Windows 10 search bar at the bottom-left. If you use multiple Windows virtual desktops, restored groups all appear on the same screen. However, you also can manually create a new Groupy window and add new tabs to it on a separate desktop.


D

Groupy

Visuals

Settings

Application Grouping

Add new tab

About

Where should Groupy position the tabs?

Tabs can either be combined with, or positioned above the titlebar. Windows with custom titlebars will always have tabs above.

Colour

Basic colours:

Custom colours:

Define Custom Colours >>

OK Cancel

Colour|Solid

Hue: 180 Sat: 240 Lum: 120

Red: 120 Green: 0 Blue: 255

Add to Custom Colours

Colours

What additional visual settings would you like to use?

☑ Tab bar should extend to full window width

More settings

Groupy is currently ON

6 EXPORTING GROUPS

Groupy has no built-in way to export or share saved groups. This can be a nuisance if you work with the same programs and files across multiple PCs. Luckily, it isn't too difficult to move your Groupy settings between Windows devices. Open File Explorer and copy your "Groupy" folder in the "AppData" directory "C:\Users\Nate\AppData\Roaming\Groupy." Do the same with "Saved Groups" under "Start Menu"—for instance, "C:\Users\Nate\AppData\Roaming\Microsoft\Windows\Start Menu\Saved Groups." Install Groupy on your Windows device, then copy these folders to their respective locations. Next, launch Groupy, and click the options button at the top-right. Scroll to "Saved Groups" and choose "Manage Saved Groups" to see them listed. Note: This only works if your files and programs are in exactly the same location on both devices.

7 CHANGE TAB BEHAVIOR

Groupy's interface is highly customizable. You can access program settings by launching Groupy via the "Start" menu or desktop shortcut. Uncheck the option to show the welcome message and click "Close." Most of the tab options are self-explanatory. In the "Visuals" section, you can choose "Combine if possible" under "Where should Groupy position the tabs?" to place tabs on the title bar itself instead of above it [**Image C**]. By default, Groupy only displays the close button on tabs when you hover over them with your mouse. To change this, click the drop-down menu under "How should the tabs look?" and choose a different option, such as "Show a close button on all the tabs."

8 CHANGE GROUPY COLORS

Groupy automatically matches your Windows color settings for custom application windows for active and inactive tabs. You also can manage these settings from the "Visuals" section of the Groupy main menu. First, deselect the checkbox marked "Automatically match color of custom titlebars." Next, click "Pick default active tab color." This brings up a color palette wheel. Select your color of choice, then click "OK" [**Image D**]. If you are unhappy with your results, click "Reset to automatic tab colors" to restore your settings. Color changes only affect the tab itself, not the file or program open beneath it.

Create a Propaganda-Style Poster

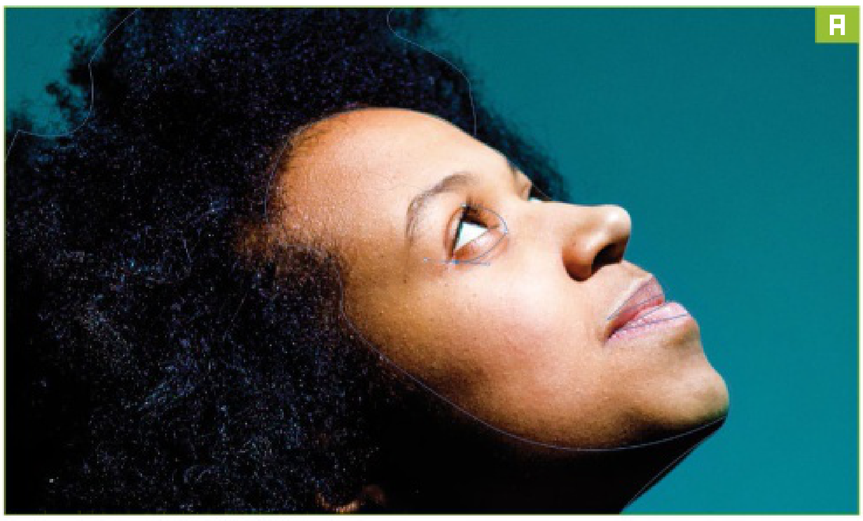
YOU'LL NEED THIS

PHOTOSHOP
Subscribe to a suitable package at www.adobe.com.

THE ART OF PROPAGANDA dates back to at least the Persian empire, which was a big thing in the Middle East 500 years BC. Evidence from further back is lost, mainly because of a lack of written records, but the idea of sending a simple message to as many people as possible is as old as mankind. Propaganda posters from the 20th century honed the idea, and frequently took simple messages and hammered them home, often using stereotypes, insults against enemies, and other low-down dirty tactics.

We're not going to try any of that here, but we can use the format of the propaganda poster to create a striking image, and we can use Photoshop to create it from a couple of photos. By cutting down the color palette, and removing almost all detail from the image, we can create something that catches the eye and can be understood from a distance, without too much reading. Any text we use will be large, in a bold color, and be comprised of as few words as possible, to make it easier for the uneducated masses to absorb the message.

One thing we've left off the finished poster is the disclaimer, required under federal law, that the message is a paid advertisement. The campaign to elect *Maximum PC's* executive editor to the office of president starts here! **–IAN EVENDEN**



1 CHOOSE SOME PHOTOS

We're aiming for a propaganda poster feel here, so are going to use a couple of faces. We've pulled some photos from a public domain image library, but you can use shots of your friends for a fun twist. Anything will do, as long as the faces are looking in roughly the right direction.

2 CREATE SECTIONS

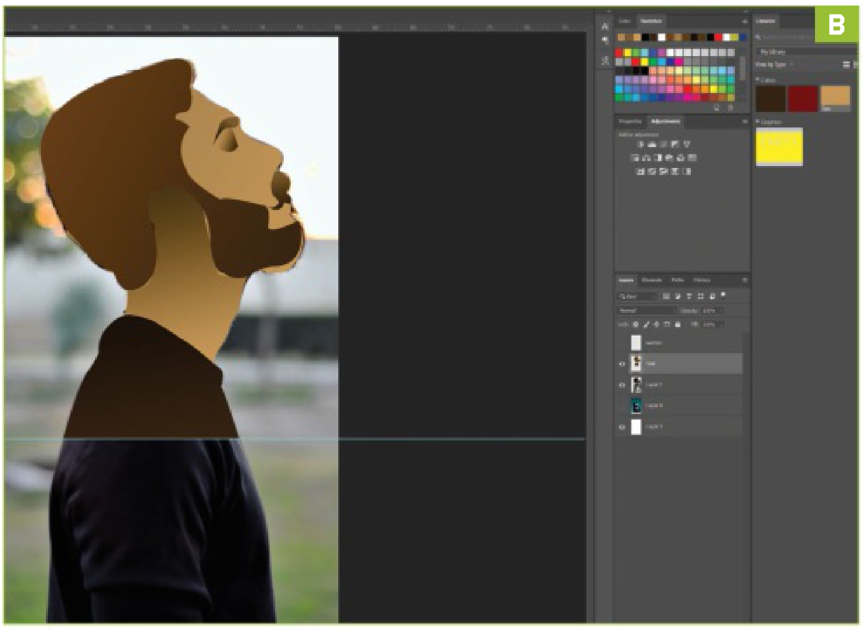
You need to chop the faces into sections [**Image A**]. We find the most comfortable way to do this is with the Pen tool, creating paths on the image we can later load as selections, but if you prefer another method—a selection brush, for example—use that instead. Sections include the whole head and shoulders, just the shoulders, mouths, and any parts of the face that are strong in contrast, such as beards. We found it useful to put a guide across the image just below shoulder level ("View → Rulers," then drag a guide from the horizontal ruler) to use as a baseline. Pull both images into the same document, on different layers, and line them up in the way you want to see in your final image before building up your selections—this saves trying to move groups of paths or selections around later. As paths and selections aren't tied to layers, saving them means we can use them on any layer later. Save as a PSD, because there's going to be a lot of layers, and Adobe's format preserves them.

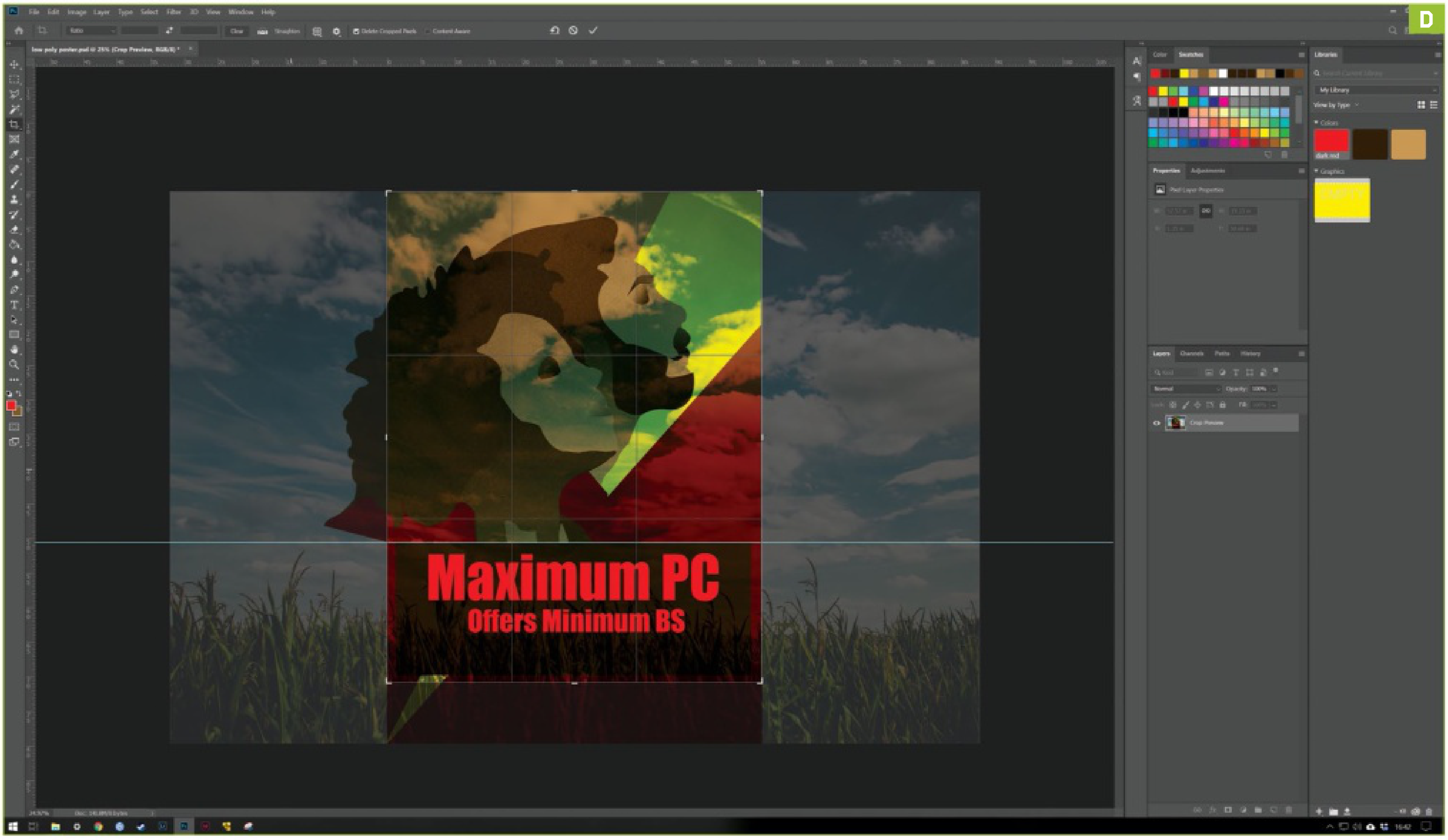
3 CHOOSE A COLOR SCHEME

You'll want a limited color scheme for this look—frequently reds, white, and blues, or the blue/orange contrast that's on every movie poster. British examples, particularly from the early 20th century, used a tan color, along with red and a darker brown, which is what we're going to use here. Use the "Add to Swatches" button on the Color Picker to make it easier to find them later—you can also automatically add the colors to any Creative Cloud libraries you've got, so you could use the same colors in InDesign later, for example.

4 GRADIENTS

We're going to fill in the sections we created with gradients, using dark and light versions of the colors we chose [**Image B**]. Try to get the darker parts to line up with shadows on the photographs, if you can. Create new layers for both faces, and load your paths as selections (or load your saved selections) one by one, creating a complete gradient head on each new layer. The Gradient tool shares a space on the toolbar with the





Paint Bucket, and blends between foreground and background colors. The length of the line you draw with the tool determines how quickly the colors blend, even when you're painting across a selection, so keep it within the outline if you want both colors represented. This can take some time, and will show up the quality of your outlines and selections—you can always add more if you need to, and tidy up the edges with the Eraser.

5

UP THE NOISE

We've placed a new background layer behind our painted people, on which there is a gradient blending between two of our chosen colors. We've also used "Free Transform" to slightly resize and rotate the faces so they're the same size and looking the same way. We used the Brush and Eraser, plus Magic Wand in conjunction with "Clear" and "Content Aware Fill" to tidy up areas where the colors didn't quite meet together. Then we added a noise layer over the top of everything by converting the two faces into Smart Objects, then running "Filter → Noise → Add Noise" on them both [**Image C**]. By applying this as a Smart Filter, we can edit it again later if we want.

6

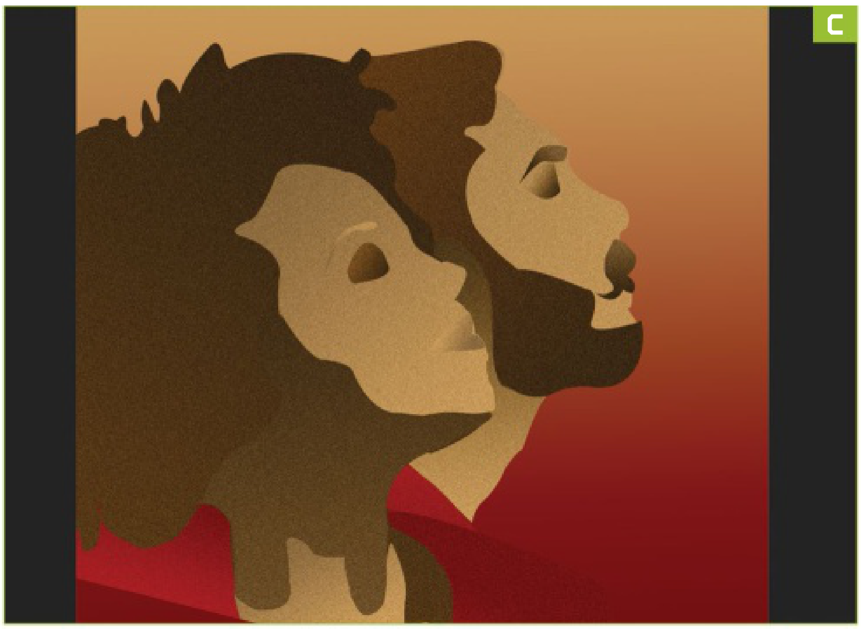
BACKGROUND AND MESSAGE

As a final touch, we've taken a photo of a summer sky and placed it right at the top of the layer stack, changing its blend mode to "Multiply." Then, just above the background layer, we've put a layer with a yellow flash on it. Still keeping within our color scheme, we've added a rectangle and some lettering, each going on a separate layer. The text is right in front, so it's not made illegible by the blended photo.

7

FINISHING TOUCHES

A quick crop to trim out the edges, and a final save in PSD format, and our message to the populace is ready to be hastily pasted on walls and store fronts all over the nation [**Image D**]. ⏻



VECTOR SELECTOR

In order to get better vector paths for our selections, we could have started in Adobe Illustrator, but according to Adobe's pricing plan, using that app would cost us three times as much each month as it does to use Photoshop and Lightroom together. So, assuming that most people subscribe to the excellent value Photographer's Bundle instead of individual apps, we've kept it entirely within Photoshop. By doing the selecting and gradient work in Illustrator, we could have imported vector artwork into Photoshop that could have been resized to anything we had in mind. While we do a tiny bit of resizing here, we have been careful not to increase the size of any elements too dramatically, in order to avoid pixelation.

Tidy Your Drives with Storage Sense

YOU'LL NEED THIS

WINDOWS 10
The OS comes with Storage Sense—you just have to make sure it's enabled.

ONE OF THE MOST IMPORTANT THINGS you can do to keep your PC running well is to ensure its storage drive isn't full of files and programs you no longer need. Over time, you'll find your drive can get clogged up with files as you install programs and download updates. The fuller a drive is, the slower it can perform, but thanks to Windows 10's Storage Sense, it's easier than ever to keep your PC clutter-free. Microsoft has designed Storage Sense to be "a silent assistant that works on your behalf without the need to configure it." This means that you can let Storage Sense work in the background, without worrying about it. However, as with any tool that removes files from your PC periodically, you should explore the settings to make sure Storage Sense is removing the correct files, and leaving anything important untouched. In this guide, we'll show you how. –**MATT HANSON**

1 ENSURE STORAGE SENSE IS ON

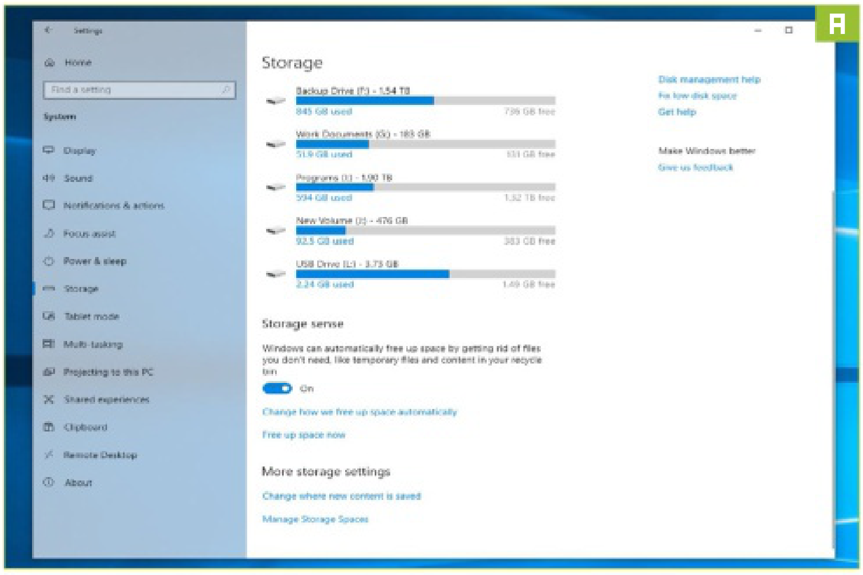
First, make sure that Storage Sense is enabled. To do that, open the "Start" menu and go to "Settings." Once there, click "System," then select "Storage." This gives you an overview of all the drives that you have installed in your PC, along with how much storage space is available. Underneath that you'll see a section called "Storage sense" [**Image A**]. Make sure this is set to "On."

2 CHANGE SETTINGS

To change how Storage Sense works, click "Change how we free up space automatically." A new window now appears, giving you various options. The first enables you to set when Storage Sense runs. By default, the tool runs whenever your drive space is low, but you can change this. Click the drop-down menu underneath where it says "Runs Storage sense" [**Image B**], and pick a schedule if you want it to run more regularly, such as every week.

3 TEMPORARY FILES

When using your computer, various apps (and even Windows 10 itself) create and store


A
Settings
Home
Find a setting
System
Display
Sound
Notifications & actions
Focus assist
Power & sleep
Storage
Tablet mode
Multi-tasking
Projecting to this PC
Shared experiences
Clipboard
Remote Desktop
About
Disk management help
Fix low disk space
Get help
Make Windows better
Give us feedback

Storage

Backup Drive (F:) - 1.54 TB
845 GB used 736 GB free

Work Documents (G:) - 183 GB
51.9 GB used 131 GB free

Programs (I:) - 1.90 TB
594 GB used 1.32 TB free

New Volume (J:) - 476 GB
92.5 GB used 383 GB free

USB Drive (L:) - 3.73 GB
2.24 GB used 1.49 GB free

Storage sense

Windows can automatically free up space by getting rid of files you don't need, like temporary files and content in your recycle bin

On

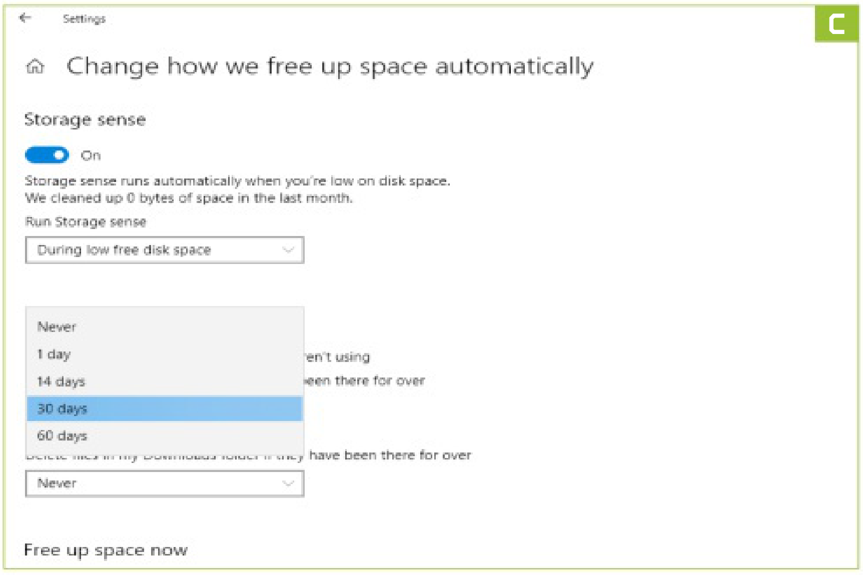
Change how we free up space automatically

Free up space now

More storage settings

Change where new content is saved

Manage Storage Spaces


C
Settings
Never
1 day
14 days
30 days
60 days

Change how we free up space automatically

Storage sense

On

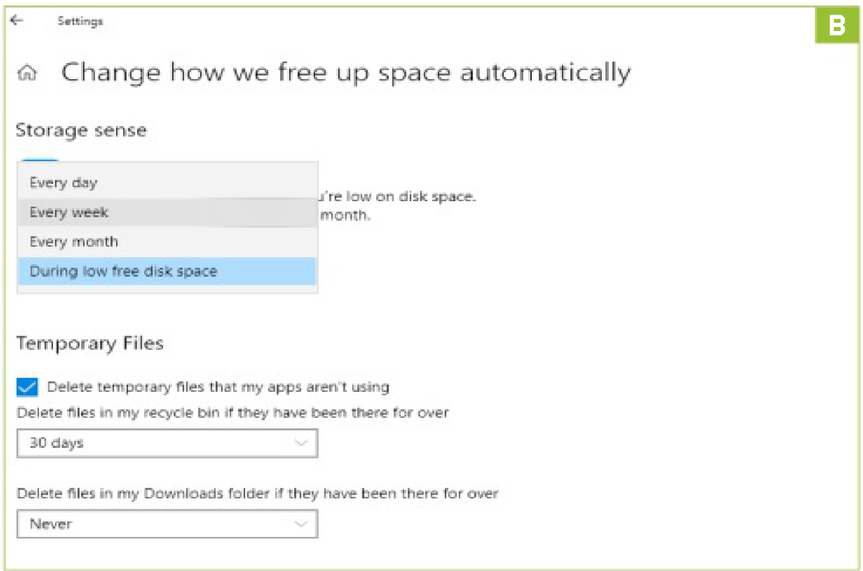
Storage sense runs automatically when you're low on disk space.
We cleaned up 0 bytes of space in the last month.

Run Storage sense: During low free disk space

…en't using
…een there for over

… have been there for over: Never

Free up space now


B
Settings
Every day
Every week
Every month
During low free disk space

Change how we free up space automatically

Storage sense

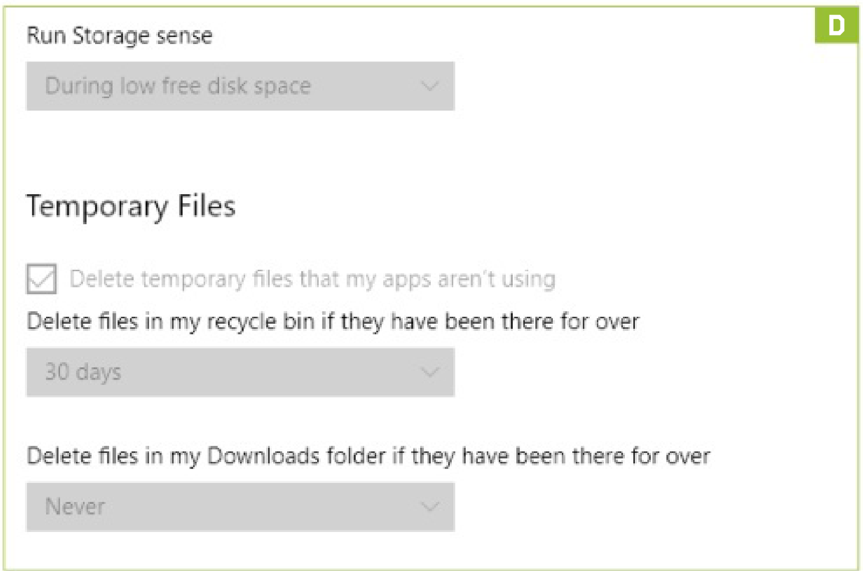
…'re low on disk space.
…month.

Temporary Files

☑ Delete temporary files that my apps aren't using

Delete files in my recycle bin if they have been there for over: 30 days

Delete files in my Downloads folder if they have been there for over: Never



Run Storage sense: During low free disk space

Temporary Files

☑ Delete temporary files that my apps aren't using

Delete files in my recycle bin if they have been there for over: 30 days

Delete files in my Downloads folder if they have been there for over: Never numerous temporary files, which are only required for a short amount of time. After that, they just take up valuable space on your drives, so it's worth allowing Storage Sense to remove those files after a set period. The default delay is 30 days, which we think is a reasonable amount of time to ensure those files are no longer needed [**Image C**]—but again, you can change this setting if you prefer.

4 DOWNLOADED FILES

Usually, when you download a program or file, it's kept in your PC's "Downloads" folder. However, even after installing a program, the installer itself is usually left in that folder, and over time, you may find that you end up with a lot of large files in there, swallowing up your storage. To remove your downloads at certain intervals, click the menu under where it says "Delete files in my Downloads folder" [**Image D**], and choose an appropriate time.

5 FREE UP SPACE NOW

If you want to use Storage Sense right now, you simply need to hit the "Clean now" button, which immediately starts the process of cleaning your PC's storage drive [**Image E**]. It uses the settings that you've selected from the rest of the page, so if you've chosen to never delete files in the "Downloads" folder, this process respects that choice. After clicking the button, you'll see a message appear on screen, asking you to wait while Storage Sense runs.

6 OTHER WAYS TO CLEAN UP YOUR PC

With Storage Sense enabled, you can leave Windows 10 to keep your drives free from clutter. However, there's also a number of other tools in Windows that can help you keep them clean. First, open File Explorer, and click "This PC" in the left-hand pane. This gives you an overview of all your PC's storage drives [**Image F**], and from there you can see how much space is on each drive.

7 USE DISK CLEAN-UP

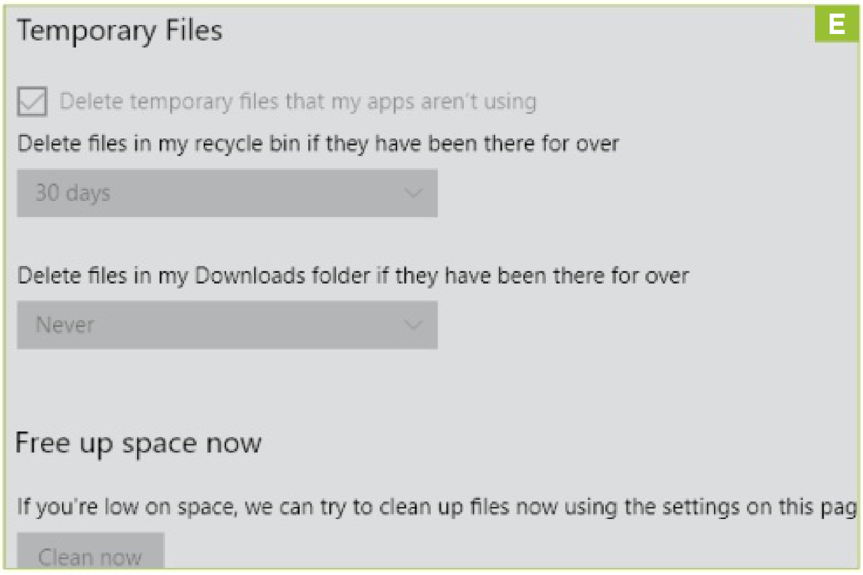
Disk Clean-up is a tool that preceded Storage Sense, and has been a part of previous versions of Windows for a while now. While Storage Sense does a lot of what Disk Clean-up used to do, the older tool is still useful. In the "Start" menu, search for "Disk Clean-up" and press Enter. In the window that opens, select the disk you want to clean [**Image G**]. This is your "C:" drive by default.

8 CHOOSE WHAT TO CLEAN

Disk Clean-up scans your PC for various files that are safe to remove, and then lists them in the window above. You'll see how much space each type of file takes up. Click the checkbox to place a check mark in it, which marks those files to be removed, then click "OK" to delete those files. For more options, click "Clean up system files" [**Image H**]. You need to be logged in as an administrator to do this. ⏻

KEEP IT SAFE!

Of course, you should be doing this anyway, but make sure you take regular backups of your most important files—that way, you won't lose anything.


E

Temporary Files

☑ Delete temporary files that my apps aren't using

Delete files in my recycle bin if they have been there for over

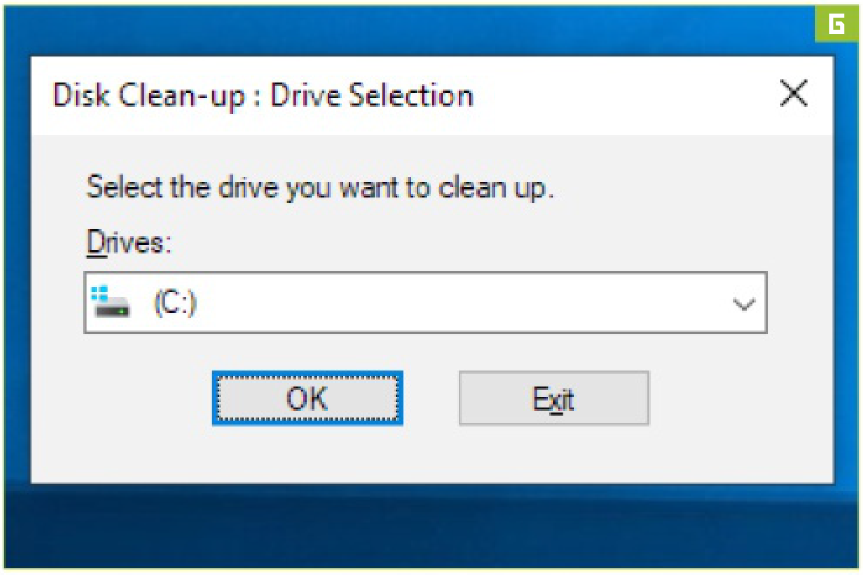
30 days

Delete files in my Downloads folder if they have been there for over

Never

Free up space now

If you're low on space, we can try to clean up files now using the settings on this pag

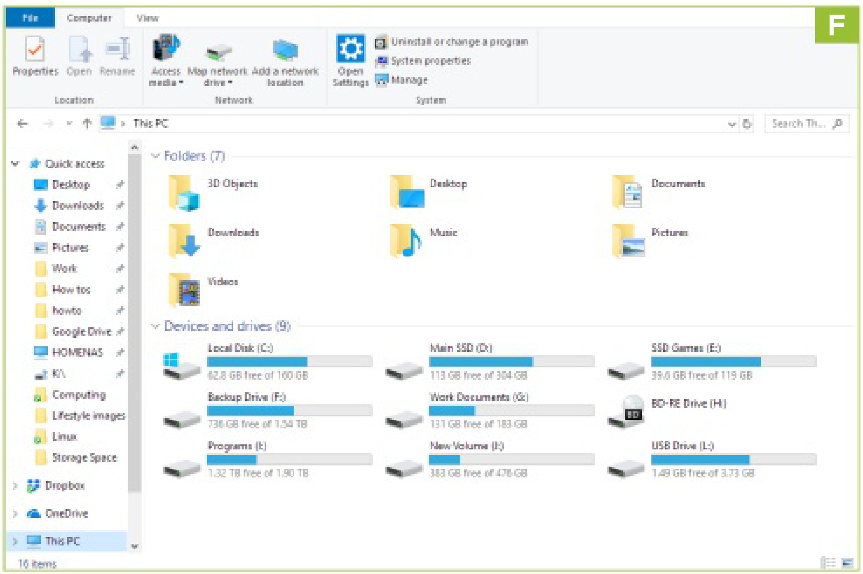

G

Disk Clean-up : Drive Selection

Select the drive you want to clean up.

Drives:

(C:)


F

File
Computer
View
Properties
Open
Rename
Location
Access media
Map network drive
Add a network location
Network
Open Settings
Uninstall or change a program
System properties
Manage
System
This PC
Search Th...
Quick access
Desktop
Downloads
Documents
Pictures
Work
How tos
howto
Google Drive
HOMENAS
K:\
Computing
Lifestyle images
Linux
Storage Space
Dropbox
OneDrive
This PC

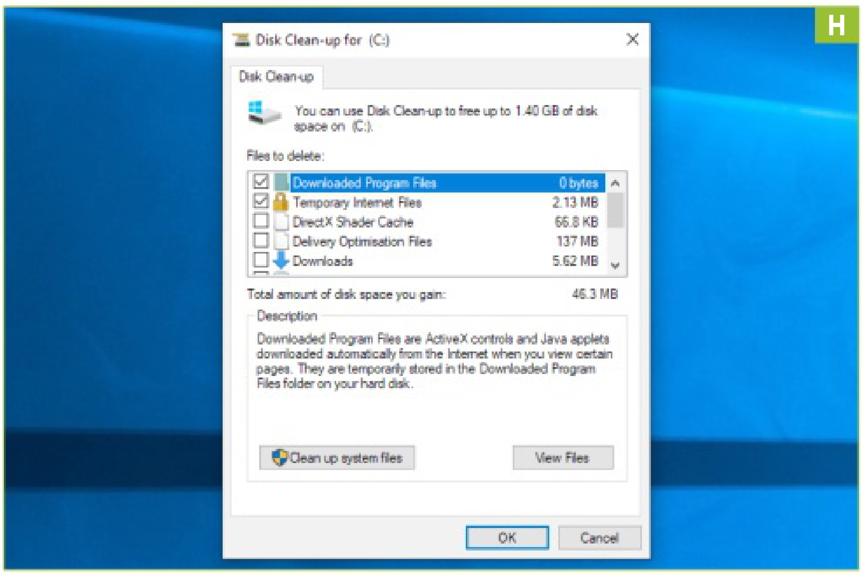
Folders (7)

3D Objects
Desktop
Documents
Downloads
Music
Pictures
Videos

Devices and drives (9)

Local Disk (C:) 62.8 GB free of 160 GB	Main SSD (D:) 113 GB free of 304 GB	SSD Games (E:) 39.6 GB free of 119 GB
Backup Drive (F:) 736 GB free of 1.54 TB	Work Documents (G:) 131 GB free of 183 GB	BD-RE Drive (H:)
Programs (I:) 1.32 TB free of 1.90 TB	New Volume (J:) 383 GB free of 478 GB	USB Drive (L:) 1.49 GB free of 3.73 GB

16 items


H

Disk Clean-up for (C:)

Disk Clean-up

You can use Disk Clean-up to free up to 1.40 GB of disk space on (C:).

Files to delete:

☑	Downloaded Program Files	0 bytes
☑	Temporary Internet Files	2.13 MB
☐	DirectX Shader Cache	66.8 KB
☐	Delivery Optimisation Files	137 MB
☐	Downloads	5.62 MB

Total amount of disk space you gain: 46.3 MB

Description

Downloaded Program Files are ActiveX controls and Java applets downloaded automatically from the Internet when you view certain pages. They are temporarily stored in the Downloaded Program Files folder on your hard disk.

Clean up system files
View Files
OK
Cancel

BUILD IT

CHRISTIAN GUYTON, STAFF WRITER

Dawn of the GeForce 1660 Ti

With the GeForce GTX 1660 series arriving, we're aiming to build a 1080p gaming powerhouse for $1,000

LENGTH OF TIME: **1-2 HOURS**

LEVEL OF DIFFICULTY: **EASY**

THE CONCEPT

AH, THE LONG-AWAITED arrival of the GeForce GTX 1660 Ti. We've been waiting for this for a while, and it's great to see it finally here. A mainstream GPU that strikes the perfect balance between price and power, the GeForce GTX 1660 Ti is Nvidia's new mid-range graphics card, capable of delivering top-notch 1080p gaming while wisely dropping superfluities such as ray-tracing support to keep the cost at a very affordable level. And now that it's arrived, we're itching to get it into a new build.

We're going with the slightly pricier MSI Gaming X GTX 1660 Ti for this build, netting us better performance—but the regular 1660 will work just fine, too, if you're trying to make small savings. The mission was simple: Assemble a fierce 1080p gaming machine for a thousand dollars. Pushing it to higher resolutions isn't important here; frame rate and general performance are the name of the game. Because of this, we were able to go for slightly more conservative pickings for the processor, motherboard, and RAM—as is often the case, the GPU is the champion of this build.

And what a champion it is. The 1660 checks in at a comparable price to the older, slower GTX 1060, while this Ti variant is faster, and handles overclocking well. It might sit below the RTX models in speed, but with 6GB of memory and trimmed fat in other areas, too, it's excellent bang for your buck. Keeping the price down proved tricky when taking storage into consideration, but eventually we had a list of ingredients. The only thing left was to, as the title goes, build it.

OVER A GRAND

OUR AIM WAS to piece together a machine for under $1,000, but we rolled in at $25 over this (although prices are in constant flux, so that may have changed by the time you read this). There are plenty of ways to stay under this budget, though, from halving the memory on offer to using a stock GTX 1660 Ti, as opposed to this overclocked version. The more enterprising among you may wish to give a Linux-based OS a shot—don't let us tell you what to do (except for in the steps below, of course).

To store everything away, we've got a budget case from Phanteks, the Eclipse P300. Inside that, we're throwing in an X470 Aorus Ultra Gaming motherboard from Gigabyte, supporting a Ryzen 5 2600 processor. Its six cores mean this PC will still be able to handle more demanding software, and like most Ryzens, the chip comes with its own AMD-branded Wraith Stealth cooler, enabling us to save a few of our precious gold coins in the pricing department. These coolers aren't flashy, but they're relatively efficient and—more importantly—compact, making them good for smaller builds like this.

That's not all we're plugging into this mobo; two sticks of G.Skill's Flare X RAM give us 16GB of memory at 3,200MT/s, plenty for the vast majority of games and applications. The GeForce GTX 1660 Ti is front and center, of course. There's only a single storage drive in this build—an Adata Ultimate SU800. Packing half a terabyte of storage, this chunk of plastic and silicon is a great budget option, making it a good choice for OS booting, while still being capable of squirreling away plenty of those big games. Lastly, this build is powered by a Corsair CX450 PSU. There was no need to go flashy on the power supply—prices have jumped up a little lately, so sticking with something simple was the way to go.

INGREDIENTS

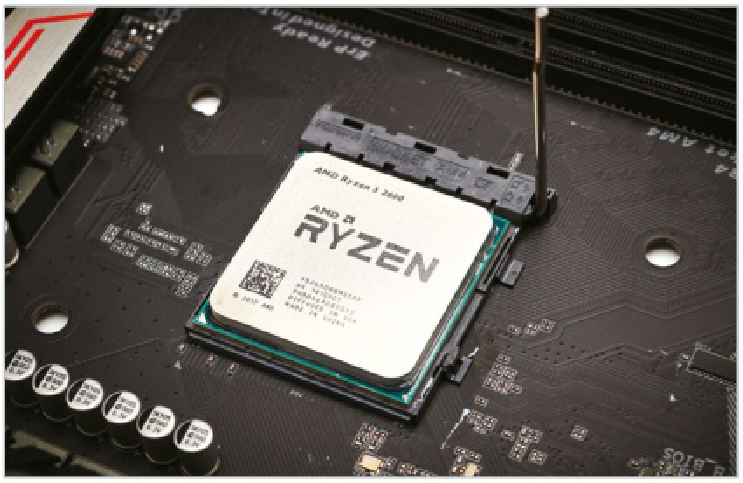
PART		STREET PRICE
Case	Phanteks Eclipse P300	$50
Motherboard	Gigabyte X470 Aorus Ultra Gaming	$125
CPU	AMD Ryzen 5 2600	$165
CPU Cooler	AMD Wraith Stealth	N/A
GPU	MSI Gaming X GTX 1660 Ti	$310
Memory	16GB (2x 8GB) G.Skill Flare X @ 3,200MT/s	$171
PSU	450W Corsair CX450	$45
Storage	512GB Adata Ultimate SU800	$60
OS	Windows 10 Home 64-bit	$99
Total		$1,025

1 THUMB WARS

CONSIDERING ITS PRICE, the Phanteks Eclipse P300 is a tasty little case to work with. Stripped down, it's a minimalistic affair; the side panels (one metal and one glass) can be removed by hand, thanks to their chunky thumbscrews. The front panel pops off with a little exertion to reveal the HDD cage, though we won't be needing access to that for this particular build. The PSU shroud is solid, which will keep the visible guts of this build nice and tidy. The metal side panel can be a hassle to fit back on, however, because it has guidance clips that need to latch into nine separate slots before it can be screwed in. The easiest way to do this is to fit the panel into the bottom three slots first, then line up the top before sliding it along toward the front of the case. These thumbscrews are rather unlikely to go back in with just your thumbs, so a screwdriver might be needed here. The P300 also comes with a Phanteks 120mm fan fitted at the rear—we got our grubby mitts on another one for a few dollars, and screwed it in at the front.

2 DARK KNIGHT RYZES

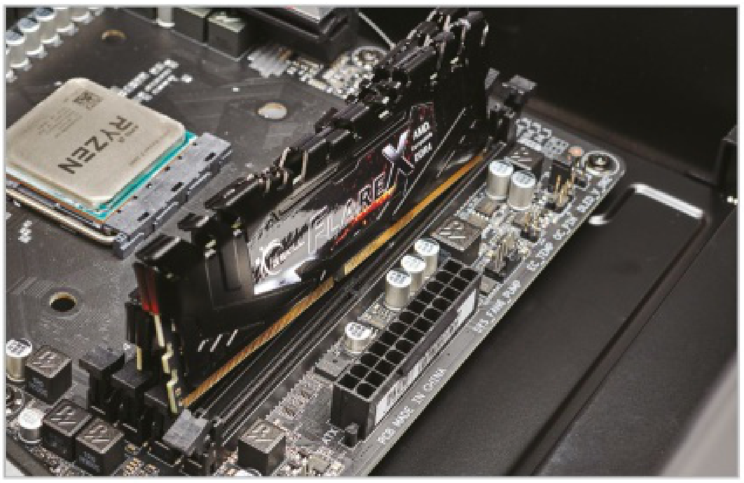
WE START WITH THE MOTHERBOARD outside the case. This X470 is a quality mobo, laid out simply, with no fancy thermal guards, and little in the way of the usual "gamer" motifs. If you don't have a dedicated test bench for PC building, setting it atop the box works just fine for this step. Ryzen CPUs are easy to install, manageable even by the most junior of builders: Just lift the clasp, carefully place the processor on to the socket, and lower the clasp back into place. Be sure to line up the highlighted corner on the CPU with the one on the motherboard, indicated by a small triangle. If you've elected to use an M.2 drive, we recommend installing it at this point as well, although as these tend to demand a premium over SATA drives, we've decided to go the cheaper route here.



3

SQUEEZED IN

BEFORE MOUNTING THE MOBO, fit the rear I/O shield that comes with it into the case. Then it's simply a matter of placing the motherboard inside the case; fit it on to the location peg, and make sure all the rear I/Os are lined up before screwing it down. The P300's pre-fitted fan can be cumbersome, as the mobo needs to fit beneath it; beefier mobos would demand relocation of the fan. As it stands, the X470 fits in under it, but it's a tight squeeze, leaving the top of the rear I/O block almost flush with the rear fan. If you're struggling, unscrew the fan from the back panel and refit it once the motherboard is installed. Once in place, we installed the RAM. As usual, this was a cinch; open the clips on both sides, slot in each stick, and push it down until the clips snap back into place.



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PRICE FREEZE

WE ARE USING the stock cooler that comes with the Ryzen 5 2600—overclockers may scoff, but this build doesn't need to do any real heavy lifting, and the cooler comes at no extra cost. It's small and fairly straightforward to install, with plenty of space even in a smaller case to screw down the four spring-fitted screws. Keeping the cooler bracket steady underneath the motherboard had us wishing we were packing an extra hand or two, but if you're doing this solo, your best bet is to prop up the bracket with a small object until you've got at least one screw in place. These screws aren't particularly long, and the springs keep them sitting at the top of their brackets, so you might need to apply some pressure with your screwdriver to get them to catch.

5

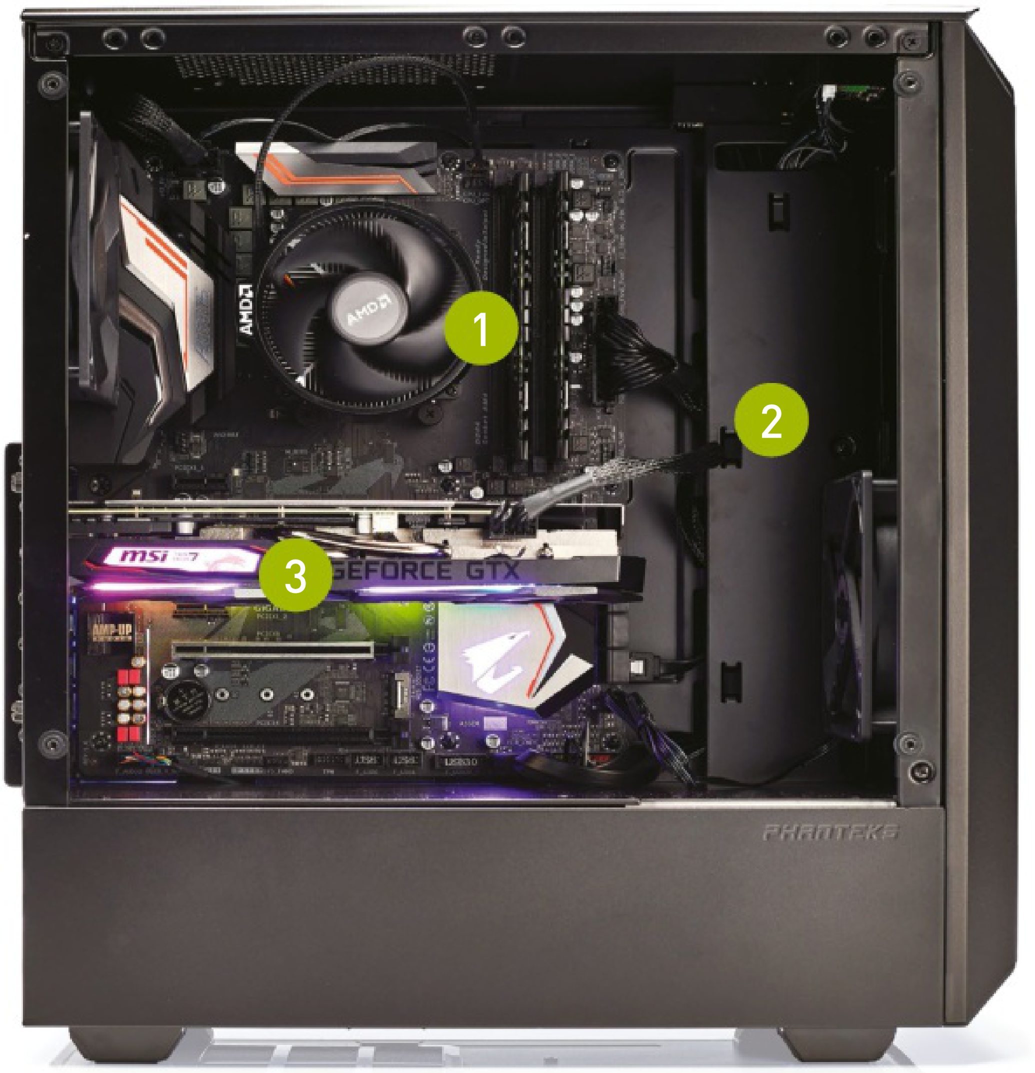
APPLE OF MY TI

NEXT, THE PRIME PIECE of this build. MSI's GTX 1660 Ti is perhaps more expensive than stock models, but it's a slick piece of gear. With Twin Frozr 7 thermal design, it's guaranteed by MSI to run cool and quiet, and comes with flashy RGB lights around the fans. This goes in easily enough—first, though, you need to remove the bracket covering the rear GPU I/O shields. Two of these shields need to come out, and while the bracket does slide up to give you a little room, removing it entirely is far easier. Keep the case on its side for this section; the GPU slots in above the M.2 slot, then screws in to the rear of the case. Don't forget to replace the bracket afterward—slide it in from the outside of the case, before securing it with the thumbscrews provided.

6

POWER STRUGGLE

LAST INTO THE CASE are the power supply and SSD. The PSU is straightforward: Once it's screwed into the backplate, the cables need to be fed through and plugged into the mobo and GPU. This can be tricky, as the gaps for the cables in this case are small. Fortunately, there's some room behind the mobo and beneath the PSU shroud for loose wiring to be tucked away. There aren't too many wires to contend with here, with only the SATA drive requiring some careful routing. The case does support Phanteks's own lightstrip tech, should you wish to spruce things up with some LEDs, but as we're not using it, those cables can be neatly packaged along with the feeds from the front I/O—Phanteks provides Velcro straps with the case for tidying up your internals. Side panels back on (carefully!), and we're wrapped up.



1 AMD's own Wraith coolers come packaged with most CPUs. These are pretty small affairs, but they do the job well enough, and save you a few bucks. As you might have guessed, we've got quite a surplus of them in the office.

2 The mounting plate is solid metal—no rubberized slots to feed cables through here. Fitting the bulkier power cables through these holes proved a bit of a squeeze, so be careful not to damage them.

3 MSI's GTX 1660 Ti Gaming X is a sweet-looking piece of gear that produces some decent graphics. More budget-friendly options are available, but you'll miss out on a factory overclock if you go down that route.

READY FOR ACTION

GETTING THIS BUILD running was unexpectedly tricky. Gigabyte motherboards can be capricious, and this X470 was no exception; upon loading Windows and investigating, we found that our 3,200MT/s RAM was running at just 2,400MT/s. Cue a venture into the BIOS setup, where we struggled to locate anything that would help—bizarrely, though, upon restarting, the memory was running at full speed, despite us not changing any settings. Sometimes, jumping into the BIOS is all that's needed.

The lack of a proper M.2 drive in this build means it's not the fastest thing imaginable when it comes to storage bandwidth, although the Adata SU800 is a reliable piece of hardware that won't demand replacing anytime soon—unless we decide to upgrade to a M.2 drive, the main thing we'd like to change about this build. That'll drive up the price of this PC significantly, but serious gamers might want faster load times. Bear in mind that this build only has enough PCIe lanes for one M.2 SSD—if you want to fit yours in the secondary M.2 slot, you need to change which port is prioritized in the BIOS.

For 1080p gaming, the 1660 Ti is a budget-friendly beast, powering through our benchmark tests, and performing well for online gaming. This build isn't going to be blasting 4K-quality rendering out, but it's efficient and quiet. While it's not an RTX GPU, a recent update made ray tracing available on this and the previous generation of GTX graphics cards—however, the trade-off in frame rate isn't even close to worth it.

The Eclipse P300 is great to work in; compact, well designed, and minimalistic, but with enough space to fit bulkier internal builds than this. Were we to keep sprucing this build up, we'd likely opt to drop a third 120mm Phanteks fan in the front, and the P300 also comes with a small integrated RGB light unit on the glass-paneled side. For those looking for a gaudier display, the case can be fitted with Phanteks RGB lightstrips, or connected to a compatible motherboard with an RGB adapter for a bit of extra cash.

The glass side panel is great for showing off your build. There's plenty of space for cable management behind and beneath the motherboard, too, so it's not difficult to keep things tidy. We didn't use them in this build, but the case has two HDD brackets at the front, should you desire extra storage. There isn't much else we'd like to change—perhaps with a bit more cash, we'd have sprung for a more powerful CPU cooler, but the included AMD one worked just fine. ⏻

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	1,152	1,258 (9%)
CrystalDisk QD32 Sequential Read (MB/s)	3,400	564 (-83%)
CrystalDisk QD32 Sequential Write (MB/s)	1,720	524 (-70%)
Rise of the Tomb Raider (fps)	60	98 (63%)
Total War: Warhammer II (fps)	46	60 (30%)
Tom Clancy's Ghost Recon Wildlands (fps)	39	51 (31%)
3DMark: Fire Strike (Index)	11,101	14,114 (27%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an AMD Ryzen 5 1600, 16GB of Crucial Ballistix Sport LT @ 2,666MT/s, an EVGA GeForce GTX 1060 3GB, and a 250GB Samsung 960 Evo M.2 PCIe SSD. All tests were performed at 1080p at the highest graphical profile.

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TESTED. REVIEWED. VERDICTIZED.

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Zotac Gaming GeForce GTX 1660

GDDR5 allows for a truly mainstream price point, balancing value against performance

GETTING MORE performance at a lower price is great, but with graphics cards, there's always a problem of competing with the previous generation. The GTX 1660 is faster than the GTX 1060 6GB, but it's not a massive upgrade. Instead, it's better positioned as a replacement for an old GTX 960 or earlier GPU; if you're using such a card, this a great upgrade, while anyone with a GTX 970 or better will probably want to wait a little longer.

The GPU at the heart of the GTX 1660 is the same TU116 as in the 1660 Ti, with two of the SMs disabled. Perhaps more interesting is when you compare it with the GP106 used in the GTX 1060. Transistor counts increased from 4.4 billion to 6.6 billion, and die size also went up. In practice, TSMC's 12nm doesn't appear to be much more than a refinement of its 16nm tech—what Intel would have called 16nm+.

The Zotac Gaming GTX 1660 is nothing fancy, though it does have dual fans for cooling. It's basically a mini-sized card that can easily fit inside small cases, measuring just 6.83 inches in length. It's a dual-slot design, and while it's technically not required, the card uses a single eight-pin PEG power connector. For video outputs, Zotac provides one HDMI 2.0b port, along with three DisplayPort 1.4 ports, and it can run all four outputs simultaneously. If you have an older monitor that requires a DVI-D connection, you'll have to bring your own adapter. There are no lights, no dual VBIOS chips, or any other higher-end features. This is a no-frills card that provides everything you need, at Nvidia's base $219 price.

The GTX 1660 uses GDDR5 memory, so it's not going to come anywhere near matching a 1660 Ti. With the Zotac GTX 1660, performance in games with the overclocked GPU is about 10 percent faster than at stock. Individual results will vary from that a little, but it's a reasonable baseline estimate. There will likely be factory overclocked models that will run faster on the core and memory clocks, and hit slightly higher speeds. The GTX 1660 does best though, when prices are kept closer to $200 than $250—at $250, you're probably better off just moving up to a GTX 1660 Ti.

Starting at 1080p, performance of the GTX 1660 is good. It's about 12 percent faster than the outgoing GTX 1060 6GB, so nothing major, but at least it's both faster and less expensive. There are a few games where the GTX 1660 isn't able to average 60fps or more at 1080p ultra, but that's only in notoriously punishing games such as *Assassin's Creed Odyssey* and *Metro Exodus*. Overall, it's a very capable 1080p gaming card—better than the 1060 6GB that launched a couple of years back, but not tremendously so. 1440p ultra is mostly a miss for the GTX 1660. Some games can break 60fps, but most run at closer to 45fps. Dropping the image quality can get the card back to 60fps, but it's better to stick with 1080p. 4K ultra is basically out of the question—the 6GB of VRAM becomes an issue with 4K ultra, games running out of VRAM and being forced to swap data out to system RAM.

The GTX 1660 takes over for Nvidia as the new "sweet spot" for mainstream GPUs. That's why the cards use GDDR5—supply and pricing on GDDR5X and GDDR6 apparently "wasn't enough" to meet the expected demand. And there's a large chunk of PC gamers running far less capable hardware, so anyone with a GTX 960 or lower may finally be tempted to make the switch. Or not, since it's still only a minor bump in performance relative to the GTX 1060 6GB for only a slightly better price.

Rather than upgrades, the biggest draw for the GTX 1660 will be with new builds—newcomers looking to set up a budget gaming PC will find plenty to like with this. It's not going to bring home any pink slips in a race, but if all you're looking for is a good 1080p gaming experience, this will do. **–JARRED WALTON**

VERDICT

9

Zotac Gaming GeForce GTX 1660

+ DUAL FAN Great for 1080p gaming; affordable; efficient and quiet.

– CRUEL SHAM Modest gains over 1060 6GB; not a true budget GPU price; some games use more than 6GB.

$220, www.zotac.com

BENCHMARKS

	Zotac Gaming GeForce GTX 1660	Nvidia GeForce GTX 1070
Assassin's Creed: Odyssey (Avg fps)	46/36	**52/38**
Deus Ex: Mankind Divided (Avg fps)	55/38	**65/45**
Far Cry 5 (Avg fps)	82/56	**101/70**
Grand Theft Auto 5 (Avg fps)	64/43	**77/54**
Metro Exodus (Avg fps)	46/34	**56/42**
Middle Earth: Shadow of War (Avg fps)	61/42	**74/50**
Total War: Warhammer II (Avg fps)	65/47	**87/61**

Best scores are in bold. Our test bed consists of an Intel Core i7-7800K, 16GB of G.Skill DDR4-3200, a Gigabyte Z370 Aorus Gaming 7, and a 1TB Samsung 970 Evo M.2. All games are tested at their highest graphical profile with AA turned up, at 1080p and 1440p.

SPECIFICATIONS

GPU	Turing TU116
Lithography	TSMC 12nm FinFET
Transistor Count	6.6 billion
CUDA Cores	1,408
Texture Units	88
ROPs	48
Core/Boost Clock	1,530/1,785MHz
Memory Capacity & Type	6GB GDDR5
Memory Speed	8GT/s
Memory Bus	192-bit

This GPU is a dependable component for 1080p gaming.

A high-end, classy rig. What more could you ask for?

Maingear Vybe

As close to perfection as it gets for a prebuilt PC

CASE DESIGN, cooling solution, noise, customer service—those are the features that make or break a modern, prebuilt gaming PC when all the hardware is top quality. Maingear lets you choose from one of four Vybe configurations or completely customize a PC based on your budget. Its top-of-the-line Vybe, the one reviewed here, is a near-perfect combination of hardware components, price, and customer service.

Included with the Vybe is a red box with a message from Maingear's CEO, a mouse pad, and a thick plastic zipper pouch filled with extra cables and other important stuff—all placed delicately under wrapping paper. Judging from this boutique-style attention to detail, Maingear cares just as much about its customers as it does its PCs.

That good first impression continues with the Vybe itself. Inside the chassis, there are two simple lighting strips—no obnoxious RGB lighting oozing out of every component. The lights dance around the components like a metallic rainbow if you have a cycling effect on—all of which can be controlled with a remote that fits in the palm of your hand.

The Vybe case is similar to NZXT's H700 series: covered bottom compartment for the power supply and HDD bays; vertical SSD SATA bays; space to mount the all-in-one liquid cooler radiator either on the top or at the front. It's easy to love this case for all the same reasons as NZXT's lineup.

However, it has metal mesh panels on top for extra airflow, and the I/O panel is on the side of the chassis, rather than the top. The Vybe has three USB 3.0 ports and one USB-C port, compared to the NZXT H700i's two USB 2.0 and two USB 3.0 ports. It also doesn't have that metal bar to the right of the motherboard like the NZXT case, which is wonderful—cable management should be a lot easier without it in the way.

The Vybe's mid-tower size is a little cumbersome, like the majority of PC cases these days, but it makes up for that with how quiet it is—exactly as hushed as the Corsair One i160, which is hard to match on the silence scale. You can tell the two apart once you throw on a graphically intensive game, but barely. This is perhaps the quietest "traditional-sized" PC ever.

There aren't any surprises in store performance-wise, as this configuration comes with an Intel i9-9900K, GeForce RTX 2080, and 16GB DDR4 RAM. The 512GB SSD is a minor downside, even if it is an M.2 NVME SSD, but assuming you're using the SSD just for games, 512GB is more than enough.

The CPU wasn't overclocked, but when it comes to benchmarks, the Vybe scored 220 on single-core performance in Cinebench and 2,175 on multicore. The RTX 2080 smashed 1080p performance with a 3DMark score of 24,930, and consistently high fps performance in our trio of in-game benchmarks on ultra graphics, hitting an average of 110fps in *Total War: Warhammer II;* 134fps in *Shadow of the Tomb Raider*; and 77fps in *Ghost Recon: Wildlands.* 3DMark scores for 1440p and 4K were 13,710 and 6,845, respectively.

Turning on DirectX 12 in *Total War: Warhammer II* dips the fps to 87. Real-time ray-tracing benchmarks in 3DMark scored 7,708 (35fps) at 1080p, but that's more demanding than current ray-tracing games. Actual in-game frame rates for *Metro Exodus* at 1080p on ultra fluctuated between 90 and 60fps most of the time. Intense combat drove the frame rate to under 60fps, but was still playable.

This system costs $2,499 before taxes and shipping charges—reasonable for the spec. Maingear also offers lifetime service labor and phone support, with a base one-year comprehensive warranty, so you'll never have to worry if something goes wrong. So, this Vybe really is a near-perfect prebuilt PC. **–JOANNA NELIUS**

VERDICT
9
KICK ASS!

Maingear Vybe

+ GOOD VIBES High-end spec list for the price; classy RGB lighting; dead silent.

− BAD VIBES Less than 1TB SSD; doesn't come overclocked; case is larger than some other PCs with the same specs.

$2,499, www.maingear.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	1,152	2,175 (89%)
CrystalDisk QD32 Sequential Read (MB/s)	3,400	1,761 (-48%)
CrystalDisk QD32 Sequential Write (MB/s)	1,720	987 (-43%)
3DMark: Fire Strike (Index)	11,101	24,930 (125%)
Rise of the Tomb Raider (fps)	60	134 (123%)
Total War: Warhammer II (fps)	46	110 (139%)
Tom Clancy's Ghost Recon: Wildlands (fps)	39	77 (97%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our desktop zero-point consists of an AMD Ryzen 5 1600, 16GB of Crucial Ballistix Sport LT @ 2,666, an EVGA GeForce GTX 1060 3GB, and a 250GB Samsung 960 Evo M.2 PCIe SSD. All tests were performed at 1080p at the highest graphical profile.

SPECIFICATIONS

Processor	Intel Core i9-9900K eight-core/16-thread 3.6GHz (5GHz turbo)
Graphics	Nvidia GeForce RTX 2080 8GB GDDR6
RAM	16GB (2x 8GB) DDR4 HyperX Predator
Motherboard	MSI Z390 A-Pro
Primary Storage	512GB Intel 660p M.2 NVME SSD
Additional Storage	2TB HDD
Cooling Solution	Maingear Epic 240 Supercooler
PSU	750W EVGA SuperNOVA B3 80+ Certified
Case	Maingear Vybe Mark V
Warranty	One-year comprehensive warranty

EVGA Z390 Dark

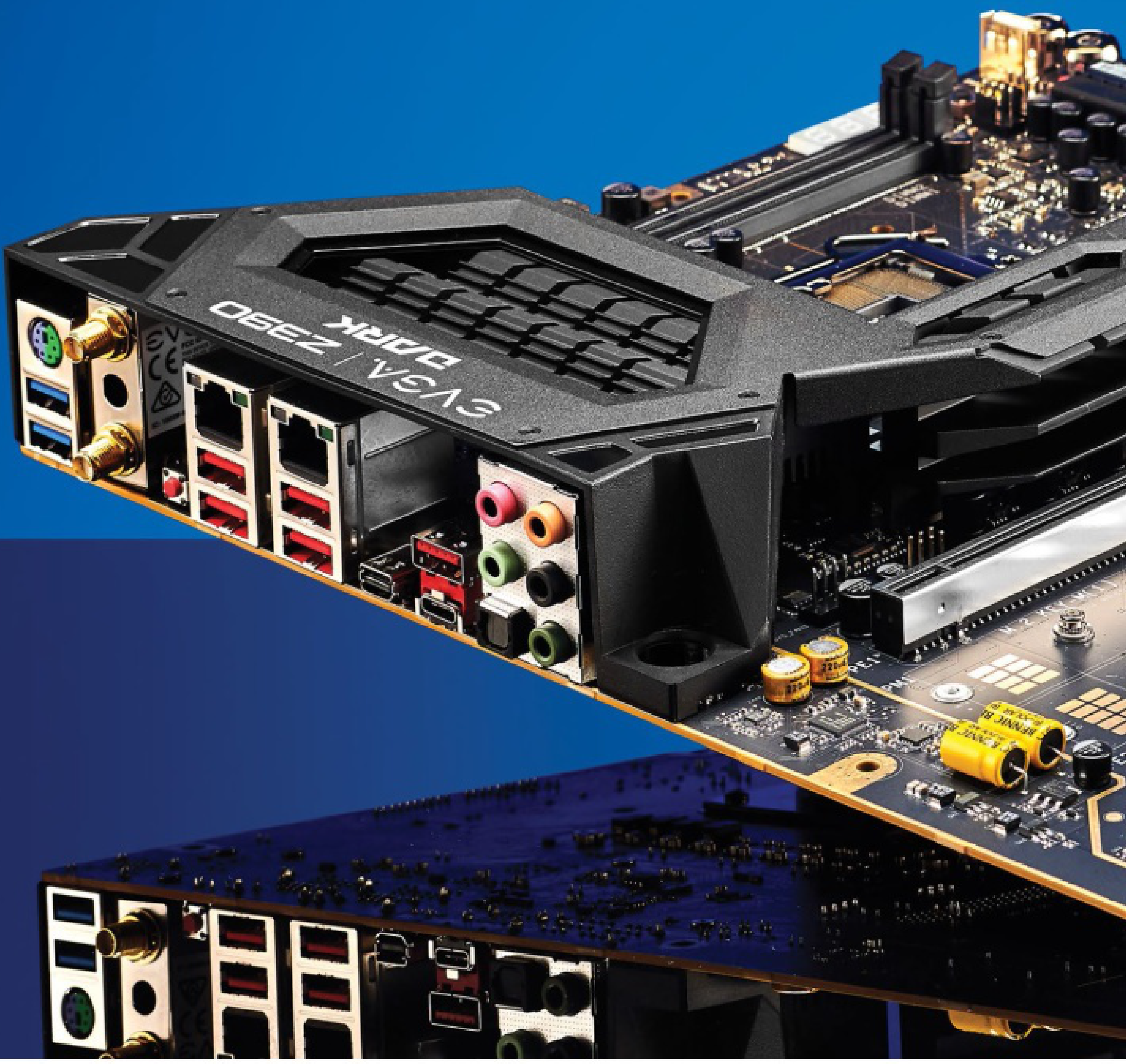
Breaking the mold

THERE'S SOMETHING SPECIAL about reviewing an EVGA motherboard. The reason is straightforward enough—these boards are always unique in their approach to how they do things. If you take a look at any other manufacturer, every motherboard layout and design follows an almost formulaic pattern. There's not a whole lot of variance between any of them. We used to muse over how all hardware followed a very similar development pattern. No manufacturer was willing to break the mold in an attempt to make something different—they were all effectively just minor tweaks to a variant that sells, regardless of what the marketing bods try to pitch to you. With motherboards, yeah the heatsinks change, and some connectivity differs here and there, but on the whole, year in year out, the only noticeable difference is the not-so-subtle increase in price. It's actually why we look for a lack of variance in our testing, rather than better performance, and consider that a good thing, not a negative, in the majority of our mobo reviews.

EVGA seems to have not got the same memo as the rest, because this board is something else. From the outset, you can tell it isn't exactly your standard layout. It's an E-ATX board, there are only two DIMMs, and both those memory slots and the CPU socket are rotated by a full 90 degrees counter-clockwise, as is the power phase design. The VRMs and MOSfets are situated under that massive rear I/O heatsink, and EVGA has decided to move the twin eight-pin EPS power connectors to just below the 24-pin, with both sets of power being right-angled to provide a cleaner look when installing your cables. On top of that you get a 17-phase power design, meaning there's more than enough headroom to overclock even the very best of Intel's Coffee Lake processors, and then there's the LN2 modes as well (with a myriad options buried in the BIOS to help overvolt the board and your chip). Plus, there's the dual BIOS debug displays, voltage reading pinouts, on-board BIOS update USB slot, hardware power buttons, and a multitude of fan headers, with the ones on the edge right-angled, and the ones on the board firing straight up. All coupled, of course, with the additional six-pin PCIe power on the bottom-left, and a rather radical cut-out 10-layer PCB holding the whole thing together. What we're getting at is that there's a lot on this thing that makes it different.

It's a quirky board, that's for sure, but we can see why EVGA has made these changes. It's definitely expensive, but it does make sense when you think about who this is for. It's designed to hit a very niche audience—well, two audiences really. The first being those who want to overclock like world record breakers (if they aren't already), and the second for those looking for something with a little more flair in the aesthetics department. The latter of which is kinda ironic, given there's zero RGB on this board (thankfully!). But it truly is a remarkable design, and one for which we can only commend EVGA. If only they'd bring this same flair to X299 and AMD (never going to happen, but a boy can dream).

Performance at stock is very much in line with what we've seen in the post-Spectre world; everything falls into position, with a few notable performance figures in Fry Render, and power draw being significantly lower than the



In pursuit of perfection.

BENCHMARKS

	EVGA Z390 Dark	Asus Maximus XI Gene
Tech ARP's X264 (fps)	29.19	**29.68**
Cinebench R15 Multi (Index)	1,369	**1,389**
Fry Render (m:s)	**2:23**	**2:23**
AIDA64 Memory Latency (ns)	49	**47**
CrystalDisk QD32 Sequential Read (MB/s)	546	**550**
CrystalDisk QD32 Sequential Write (MB/s)	375	**495**
Power Draw Idle/Load (Watts)	47/**301**	**42**/307
Total War: Warhammer II (Avg fps)	**56**	**56**
Lowest Voltage @ 5.0GHz (Volts)	1.26	**1.22**
Maximum OC Achieved (GHz @ V)	5.1 @ 1.34	**5.1 @ 1.32**

Best scores are in bold. Our test bed consists of an Intel Core i7-8700K, 16GB of Corsair Dominator Platinum DDR4 @ 3,200MT/s, an Nvidia GeForce GTX 1080, and a 250GB Samsung 850 Evo. *Total War: Warhammer II* was performed on the ultra preset at 1440p.

competition. In our overclocking tests, there's a ton of room to really work a solid OC on your chip. We couldn't quite match the frequencies and voltages we've achieved on some Asus motherboards in the past, but it's not a BIOS we're particularly familiar with. Given time (we're talking months here), there's plenty in it, so we're sure we could coax out better voltages and a higher clock.

Speaking of BIOS, the Z390 Dark's version is nothing but stunning. It looks incredibly clean, especially for base-level software, and even comes with an AI overclocking feature on the main home screen after you mash Delete. It overclocked our chip to 4.9GHz on auto, with 1.25V, and maintained a 70 C figure on it, too—more than comfortable for everyday work on a Core i7-8700K.

Ultimately, the Z390 Dark is a truly impressive motherboard, and an incredible departure from what we've come to expect from that almost-carved-in-stone formula we've seen from every other manufacturer. Its BIOS is impeccable, and on the whole, its feature set is rich enough for those willing to lay down the cash for it. It's expensive, and we get that it's not for everyone, but if you need the absolute best that Z390 can offer, we'd argue there's little out there that competes with the EVGA Z390 Dark right now. **–ZAK STOREY**

VERDICT
9

EVGA Z390 Dark

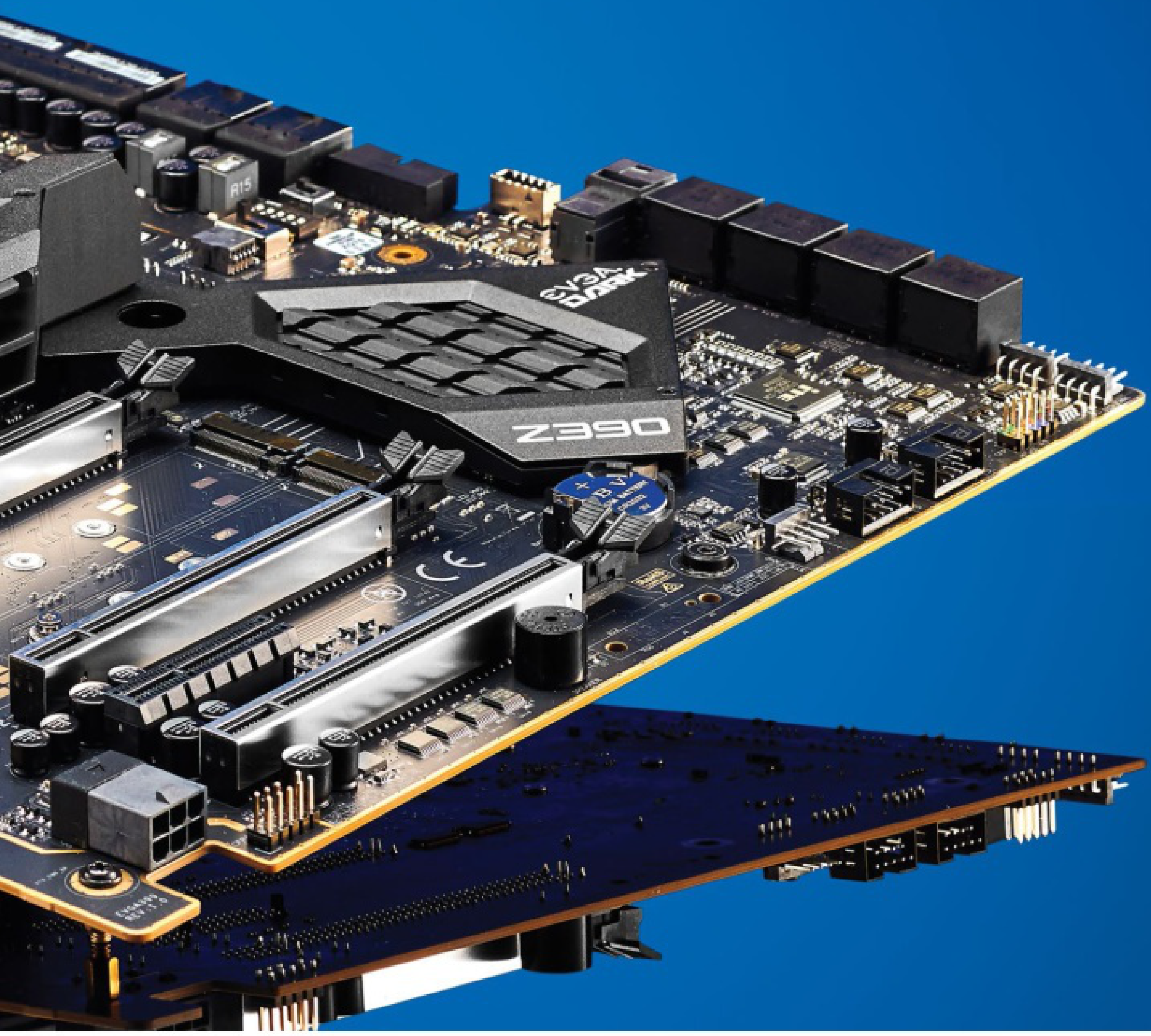
+ THANOS Impressive design; overclocking heaven; industry best BIOS; looks incredible; no RGB.

– DC UNIVERSE Price.

$500, www.evga.com

SPECIFICATIONS

Chipset/Socket	Z390/LGA1151
Form Factor	E-ATX
Memory Support	32GB (2x 16GB) @ 4,600MHz
M.2/U.2 Support	2x M.2, 1x U.2
SATA Support	8x SATA 6Gb/s
Max PCIe Support	3x 16 (x8x4x4)
Rear I/O	7x USB 3.1 Type A, 1x USB 3.1 Type C, Mini DisplayPort, 2x Intel Gigabit Ethernet, wireless A/C, PS/2 combi port, 5.1 audio out, optical audio out



EVGA
NU AUDIO
Engineered By Audio Note
LINE OUT
HEADPHONE
LINE IN
MIC IN
S/PDIF OUT
DESIGNED BY EVGA
RoHS COMPLIANT
V:1.0

That shielding across the PCB keeps the electrical interference at bay.

EVGA Nu Audio

We didn't hear this one coming

LAST ISSUE, WE ASKED a question in one of our features that seems to have been on the lips of PC users for the last 25 years: Do you need a soundcard? This issue, we ask simply: Do you need this one? Stylistically and on the spec sheet, EVGA's high-end Nu Audio discrete soundcard is aimed squarely at gamers, but in truth, this is as much about enjoying better music as it is being able to hear *Fortnite* sound cues.

Let's start with the headline numbers: Playback and recording formats go up to 384kHz, 32-bit audio, signal-to-noise ratio is nice and high at 123dB, and there's a generous array of ins and outs comprising stereo and headphone-outs, 3.5mm line and mic-ins, an optical-out, and front panel header. There's also, rather inexplicably, an RGB lighting panel on the card itself, which is customizable via EVGA's Nu Audio software. We can get on board with RGB on keyboards and even graphics cards these days (just as long as we can turn it off or program the color profiles to our taste), but unless your case has an inverse arrangement inside, like Corsair's 600C, you simply won't see the RGB on this soundcard.

Installation is very similar to that of a GPU: Slide it into a free PCIe slot, hook up a power cable, and attach the header to the side of the card. This is a minor niggle for cable management virtuosos, because it would have been much easier to keep things tidy if both connectors were at the back. As it is, you'll have to get creative with cable ties if you want to preserve the clean lines inside your case. Unlike many external DACs, however, this card requires its own drivers to work, so there's marginally more fuss to the setup than you'd find from something like the Woo Audio WA7D Fireless. The offset is that you get the benefits of EVGA's software for your troubles, although frankly it's nothing particularly special. It's a basic offering, which allows control of inputs, and features six custom EQ profiles. The user has to create all these profiles, however, and that's disappointing, given this card's high price point—a handful of basic profiles for different music genres or activities would have been nice. Compounding that downer, it's actually quite confusing to save and apply these EQ profiles yourself. Iterations are needed on EVGA's part to make this side of the bargain seem like much more of a meaningful benefit.

However, once you hook up some speakers or headphones to the card, you immediately understand the advantage of this hardware. It's an incredibly clean and warm sound, which gives audio sources space to breathe, and gives your ears the chance to hear the subtle details you might otherwise have missed. It inspired us to revisit that holy grail of atmospheric in-game sound, *Thief: The Dark Project*, and 20 years on, it's never sounded better. *Fortnite* and *PUBG* don't offer quite the same amount of raw atmospherics, but their soundscapes become clearer using the Nu Audio and our BeyerDynamic DT770s than most gaming headsets allow. You can almost hear the chicken dinner roasting. Whether it improves gaming performance is a question best left to those at the apex of esports. There are too many other variables impacting our performance here at amateur (read: "terrible") level, so there's only so much you can read into the fact that we didn't instantly become better battle royale or online shooter players. For us, it's sufficient that the difference is so discernible compared with an onboard sound or USB gaming headset setup.

Except for its lackluster accompanying software, the Nu Audio does everything it's supposed to: staggeringly better sound than you would achieve from onboard sound chips, ease of use, and strong I/O options. It's not for home recording, folks, but it checks the boxes confidently for gamers. **–PHIL IWANIUK**

VERDICT 8

EVGA Nu Audio

+ NU METAL Easy setup; clean, warm tone.

− LIMP BIZKIT No EQ presets; software could do more.

$250, www.evga.com

SPECIFICATIONS

Audio DSP	XMOS xCORE-200
Outputs	2-channel (analog), 5.1-channel (S/PDIF)
Dynamic Range/ Signal-to-Noise Ratio	123dB
Playback Format	Up to 384kHz, 32-bit
Headphone Amp	ADI OP275
Recording Format	Up to 384kHz, 32-bit
I/O	Stereo-out (RCA L/R), headphone-out (6.3mm), line-in (3.5mm), mic-in (3.5mm), optical-out (TOSLINK pass-through), front panel header, PCIe x1 Gen2 interface

ASUS
Audio by harman/kardon
vera

Asus's new 38-incher
is ace at minimizing
cable clutter.

Asus Designo Curve MX38VC

A premium productivity panel, but at a price

NOT INTO GAMING? Then it's easy to get the feeling PC monitor makers aren't interested in having you as a customer. After all, so much recent innovation centers around improving gaming performance. We're talking high refresh, adaptive synching, even HDR up to a point.

Of course, what makes for a great gaming panel can be beneficial in other areas. HDR is a case in point. But when it comes to productivity, stuff like adaptive sync and high refresh? Not so much. Instead, if you have a solid budget to play with, what you primarily want is a nice, big, high-quality panel with lots of pixels.

What you want, on paper at least, is the Asus Designo Curve MX38VC. With a 38-inch IPS panel and 3,840x1,600 pixels, it checks all the really important boxes. It also adds a few frills that may help seal the deal, not that you're likely to feel you're getting a bargain at over $1,000.

It's not quite the first such monitor we've seen. The LG 38UC99 sports the same panel spec, including the 21:9 superwide aspect ratio, 2300R curvature, and thin bezels on three sides. Indeed, it's almost certainly the same LG-produced panel in both monitors. Both also support USB Type-C, which is great for reducing cable clutter, and even better if you drive your screen with a laptop, given it supports simultaneous charging.

Speaking of charging, one of the MX38VC's party tricks is wireless charging for Qi-compatible devices. There's a charging pad built into the base of the stand, which can charge devices even when the display is asleep.

Another surprising feature is the integrated Harman Kardon sound system, with support for Bluetooth audio streaming. We don't want to overstate the quality of audio it produces—even a fairly cheap 2.1 speaker setup would match and probably exceed it—but there's reasonable dynamic range and definition on offer, and overall it's an absolutely livable if not truly enjoyable audio solution. Factor in the USB-C, charging dock, and built-in speakers—oh, and a triple-port USB 3.0 hub—and you have a monitor that promises to reduce cable clutter to an absolute minimum.

But what of the image quality? It's pretty much what you'd expect, given the specs. This isn't an HDR panel, so the visuals are quite subdued, but the factory calibration is sound, with no obvious flaws in any of our test images. It's an IPS panel, so the colors are very convincing, the contrast is good rather than excellent, and the viewing angles are outstanding.

As for how that 3,840x1,600 resolution maps to the 38-inch panel, the result is an unspectacular 110 ppi. This is not a high-density display. That said, the sheer pixel count ensures plenty of desktop real estate, especially compared to many other superwide monitors, which tend to offer limited vertical resolution. If you want to run multiple documents, webpages, and applications side by side, the MX38VC is very sweet, that's for sure.

What's more, while it's not a gaming monitor, it's still pretty breathtaking if you fire up something good-looking like *Witcher III.* The size of the panel and the wide aspect ratio make for an immersive experience. Adaptive sync helps, too, although the fun is capped to 70Hz.

All in, this is a very nice monitor for general computing. Our only reservation is the lack of HDR support. In 2019, the absence of HDR on a premium panel priced north of $1,000 is conspicuous. It's not necessarily a deal-breaker, but it does compromise the MX38VC's value proposition. **–JEREMY LAIRD**

VERDICT

8

Asus Designo Curve MX38VC

+ THUNDERBOLT High-quality panel with lots of pixels; strong peripheral features.

− PARALLEL PORT Very expensive; no HDR or high refresh.

$1,099, www.asus.com

SPECIFICATIONS

Panel Size	37.5-inch
Native Resolution	3,840x1,600
Pixel Density	110 ppi
Panel Type	IPS
Maximum Refresh	70Hz
Response	5ms
Contrast	1,000:1
Display Inputs	2x HDMI, DisplayPort, USB-C
Connectivity	3x USB 3.0
VESA Mount	No
Warranty	Three years

Dominator Platinum RGB 32GB DDR4 3,600MHz C16

Corsair mixes things up with its flashiest RAM yet

CORSAIR'S DOMINATOR LINE is nothing if not striking. In stark contrast to its small, slick Vengeance series, the Dominators are heavy metal sticks that stand tall in your motherboard's RAM slots. The Dominator Platinum RGB has the addition of a dozen individually addressable LEDs along the top of each stick, enabling a variety of flashy RGB effects courtesy of Corsair's iCue program. We're reviewing the 32GB 3,600MHz CL16 model; a high-powered four-piece set that will set you back over 500 bucks.

Do they look good? Without a doubt. iCue's preloaded patterns make for some seriously funky options, making these perhaps the greatest choice for builders looking to show off their rig's internals. Want a rainbow spiral revolving around your entire mobo? It's got you covered. Color-coding to denote the temperature of your CPU? You've got it. It's surprising Corsair hasn't figured out a way to let us play *Tetris* on these little LED stacks.

We're not the biggest fans of over-the-top lighting, but it's hard to deny how cool these can look. More important, though, is performance. We had to meddle with the BIOS settings to get this RAM to work; if you're running this on an AMD-compatible mobo, be prepared to spend time in the BIOS to get the settings right.

While possible in theory, we struggled to get this RAM running at 3,600MHz on an AM4 motherboard. Switching to an Asus Prime X299-Deluxe, we had it up and running smoothly enough (a hasty mash of the CMOS clear button was required, though). Once we got things going, it was hard not to be impressed; hefty memory bandwidth and tight latency make it clear that this RAM is not to be messed with. It also demonstrated speedy zip and unzip times, but our other tests showed little to impress; this isn't going to blow any other DDR4 memory out of the water.

Pricing is obviously a key concern when upgrading RAM, and the Platinum RGB ain't cheap. This isn't memory for the faint of heart or the slender of wallet. Per gigabyte, it costs more than pretty much every other 32GB RAM kit on the market right now, but the smooth 3,600MHz means that there isn't much it'll struggle with. When it comes down to it, it's difficult to unreservedly recommend the Platinum RGB; while the latencies are relatively low, there are faster kits, and they tend to be cheaper. The need for 32GB of memory is up for debate as well; 16GB is often sufficient, but that's an argument for another day. Size is also a concern; the overhead on these sticks is significant, meaning that it might be incompatible with bulky coolers.

If RGB is your thing, this is impressive. iCue makes for a great selection of color and pattern customization—combining this with other RGB products from Corsair can result in a veritable lightshow. For builders looking to make an uber-stylish rig, the Dominator Platinum RGB is a solid choice. **–CHRISTIAN GUYTON**

VERDICT

8

Corsair Dominator Platinum 32GB 3,600MHz

⊞ **HEADLIGHT** Stunning appearance; fully addressable LEDs; good performance.

⊟ **GOODNIGHT** Heavy and tall; high price per gigabyte; AMD compatibility issues.

$530, www.corsair.com

BENCHMARKS

	Corsair Dominator Platinum RGB 32GB 3,600MHz	G.Skill Flare X 32GB 3,200MHz	Corsair Dominator Platinum 32GB 2,400MHz
SiSoft Sandra Memory Bandwidth (GB/s)	**67.7**	64.9	55.8
SiSoft Sandra Memory Latency (ns)	26.3	**25.6**	29.7
Cinebench R15 (Index)	**3,130**	3,084	3,111
Rise of the Tomb Raider (fps)	**125**	124	124
FryBench Time to Complete (m:s)	**1:10**	**1:10**	1:11
25GB 7-Zip Compression Time (m:s)	**5:58**	6:12	6:38
25GB 7-Zip Decompression Time (m:s)	**2:30**	**2:30**	2:38
Price per Gigabyte	$16.56	**$13.90**	$14.38

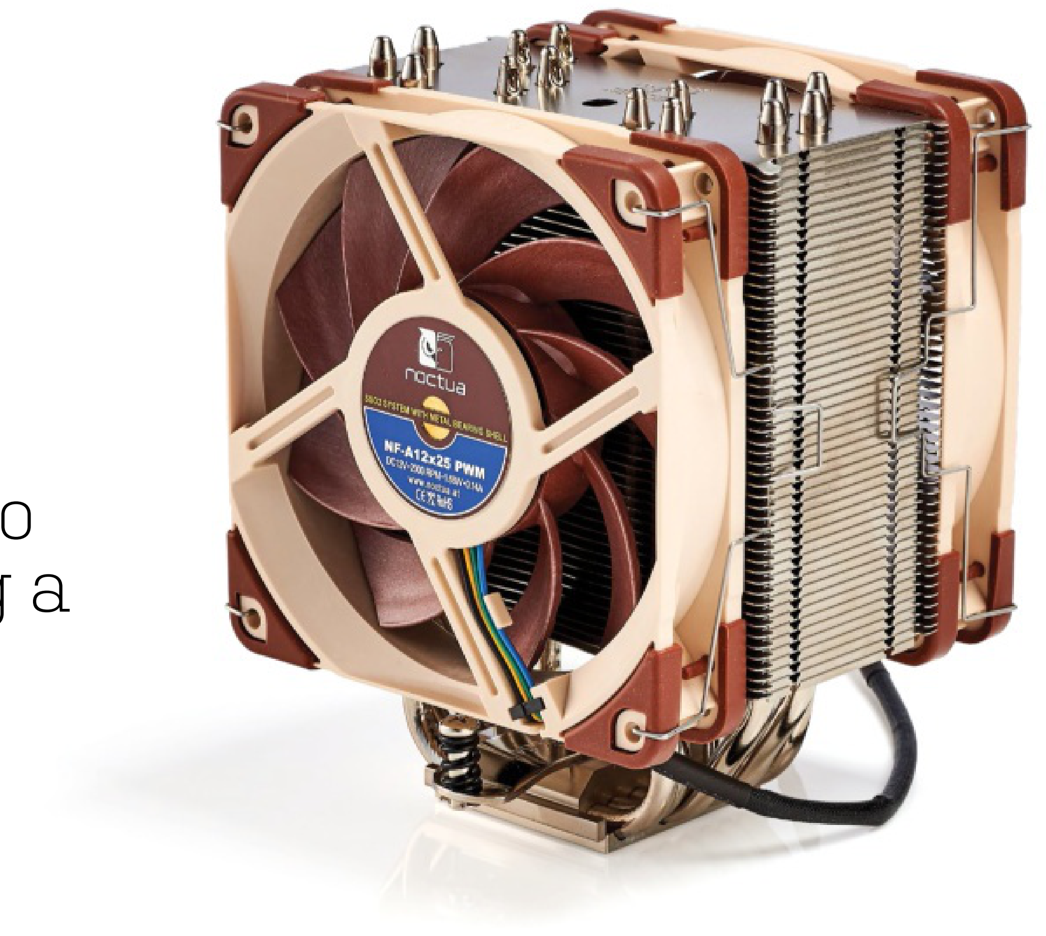
Best scores are in bold. Our test bench consists of an Intel Core i9-7960X, an ASUS Prime X299-Deluxe, a Nvidia GeForce GTX 1080 and a Samsung 850 Evo 250GB SSD.

SPECIFICATIONS

Capacity	32GB (4x 8GB)
Speed	3,600MT/s
Latency	16-18-18-36
Memory Type	DDR4
Voltage	1.35V

Noctua NH-U12A

Noctua's newest CPU cooler is out to give water cooling a run for its money



NOCTUA'S LATEST COOLER is big. Yes, it's 120mm standard, but with fans mounted on both sides of a beefy heatsink, it takes up a lot of space inside your case. It's not too big to handle, though, with an asymmetric design that ensures it can fit alongside your RAM and GPU even if you're filling every slot on an AM4 or LGA115x motherboard. Noctua fully redesigned its heatsink model for the NH-U12A, the new design featuring seven heat pipes (as opposed to the conventional six) and increased fin surface area. The heatsink is 6.2 inches (158mm) tall, meaning that it won't fit in some smaller cases, but this size ensures its capability. The objective was to deliver a 120mm cooler that could perform at the same levels as 140mm ones, and Noctua has succeeded there. With both fans attached, this cooler is bulky, but it can still comfortably squeeze in between the RAM and rear I/O shroud—quite an achievement.

The fans are Noctua's 120mm NF-A12x25 PWM models, which come in their typical brown and beige color scheme, evoking the faintly kitschy computer design aesthetics of the pre-2000 era. The wire brackets that attach them are awkward, but ultimately quite secure, rubber pads ensuring minimal vibration during use. Looking past this, it's hard to fault these fans; they run whisper-quiet, and ensure good airflow through the heatsink. Pulse-width modulation support means they deliver variable RPM based on the temperature of the CPU. There's always the option to remove one and fit it into the case instead, too.

It's not the easiest cooler in the world to install. As always, getting the backplate to remain in place while you secure the first screw is a hassle, but that's the case with any heatsink—a bigger issue is the thick plastic washers and the two spring-loaded screws on the base of the cooler tower. There's a lot in the box; the U12A can be fitted to any AM-series AMD motherboard as well as Intel-compatible LGA-115x and LGA-20xx models, so it comes with a variety of brackets and screws, and backward compatibility with older mobos is a pleasant addition. The cooler comes with the fans attached to the heatsink, but they need to be removed in order to install it, and they can be tricky to reattach.

STRESSED TO KILL

This cooler does its job well. Even running multiple benchmarking programs at once (we forgot that Prime 95 considers the "close" button to be a mere blue-sky suggestion, and accidentally left it running in the background as we opened Cinebench), our CPU temperature barely reached 60 C. At idle, the Ryzen 5 2600X sat comfortably below 30 C. It's not noisy, either—even stress tests that had the fans running at full pelt weren't producing much noise, and while idling they were almost inaudible. It handles overclocking well, too; without raising the voltage, we pumped up the CPU to 4.2GHz, and the Noctua easily outperformed a standard AMD Wraith Stealth running at stock clocks. This cooler means business—it'll keep overclocked CPUs cool even when running more demanding software. Our system crashed repeatedly during overclocked processor stress tests with the Wraith Stealth, while the U12A kept us afloat.

The main downside here is the cost. For a cooler devoid of any liquids, $100 is a steep price to pay—even if the performance is undeniable. It's still cheaper than an all-in-one cooler of similar quality, though, so if you don't like the idea of liquid cooling, it's an excellent choice. Is it perfect? Not quite. The chunky design, objectionable color scheme, and overly complicated installation process hold this cooler back a little, but it does perform excellently. It might not be as elegant a solution as a high-tech AIO cooler, but you get your money's worth—even if the price isn't exactly low. –**CHRISTIAN GUYTON**

VERDICT
9

Noctua NH-U12A

+ **HEATSINK** Runs quietly; new heatsink design; good for overclocking.

− **ICE RINK** Costly for a fan cooler; bulky; tricky to install.

$100, www.noctua.at

SPECIFICATIONS

Socket Compatibility	Intel LGA1150, LGA1151, LGA1155, LGA1156, LGA2011, LGA2066, and AMD AM4, AM3(+), AM2(+), FM1, FM2(+)
Cooler Size	120mm
Cooler Dimensions	6.2 x 4.6 x 4.4 inches
Cold Plate Material	Copper
Fan Airflow	60.1cfm
Fan Noise	18–23dBA
Warranty	Six years

HyperX QuadCast

Testing, testing… Is this thing on? HyperX enters the streamer mic market

TEN YEARS AGO, if someone had told you that gaming peripheral makers would one day move into production of high-end gamer-branded microphones, you'd have had a pretty hard time joining the dots. To the older generation here at *Maximum PC,* it doesn't seem so long ago that a swingarm mic on a headset was considered a luxurious boon.

But the advent of YouTube and Twitch have changed the face of gaming in many ways. For those who stream themselves playing, it's essential to offer their audience the clearest audiovisual experience possible. And for those who watch those who stream themselves playing, that high-end equipment is deeply aspirational. So, here we are with a $140 USB microphone on our desk.

And let's get this out of the way: A very good one it is, too. The spec sheet doesn't really tell that story, though—there isn't much to distinguish the QuadCast from its competitors, such as the almighty Blue Yeti or Razer's Seiren series mics, when it comes to frequency response (an ample 20Hz–20kHz) or sample and bitrate (CD-quality 48kHz/16-bit).

Indeed, since we aren't generally as well trained at spotting great mic attributes in the gaming community as a great graphics card, the suspicion might be that perhaps "gaming" mics are simply cheaply produced and low-quality studio mics, but that's not the case. The QuadCast really is suited to gaming.

That's because of the little details. First is that it's supplied with a shock mount, which keeps the microphone itself from picking up every little knock and scratch from your desk. It might sound like a minor point, but if you've ever imposed the red light of terror on yourself and streamed live, you know how much of a difference it makes. There's also a mic stand adapter included, so you can set the QuadCast up on a boom arm above yourself or to one side.

The controls are also perfectly suited for gaming. We particularly enjoy the touch-sensitive mute control positioned at the top of the mic. Just a tap and it's muted or back on, without any of the clicks or pops that often creep in when a mechanical switch operates the mute function. And if you were in any doubt, there's a red light that lets you know whether the microphone's on or not. Controlling the gain is also simple enough to achieve mid-stream via a dial at the bottom of the mic. Again, it's free of pops and crackles.

POLAR BLARE

It's also nice to have the option of a few different polar patterns, although you'll generally want to stick to the narrower cardioid pattern for solo streaming, to avoid picking up background noise. The stereo option is handy for podcasting with one other person, and the omnidirectional pattern can handle groups of more than two, although background noise does naturally increase as a result. In cardioid configuration in particular, the recording and broadcasting sound quality is really exceptional, easily on a par with similarly priced studio mics at recreating vocals. Sibilant sounds are captured brilliantly, and the high end is noticeably detailed—it's lacking the warmth of pricier studio mics, but you'd expect that from a sub-$200 USB mic aimed at gamers.

And thus our only real reservation with the QuadCast isn't specific to the product at all, but gaming microphones as a "prosumer" prospect. Investing in an XLR audio interface and a studio mic yields better results and more options for home recording, and although the QuadCast makes the best case yet for choosing an option tailor-made for gaming, with its easy controls, from a consumer standpoint, it's still less desirable than a pro audio solution. Still, HyperX's mic is a galaxy away from the swingarm mics on gaming headsets. For the vast majority of users, that'll be enough to warrant a place for that shock mount on their desks. **–PHIL IWANIUK**

VERDICT 9

HyperX QuadCast

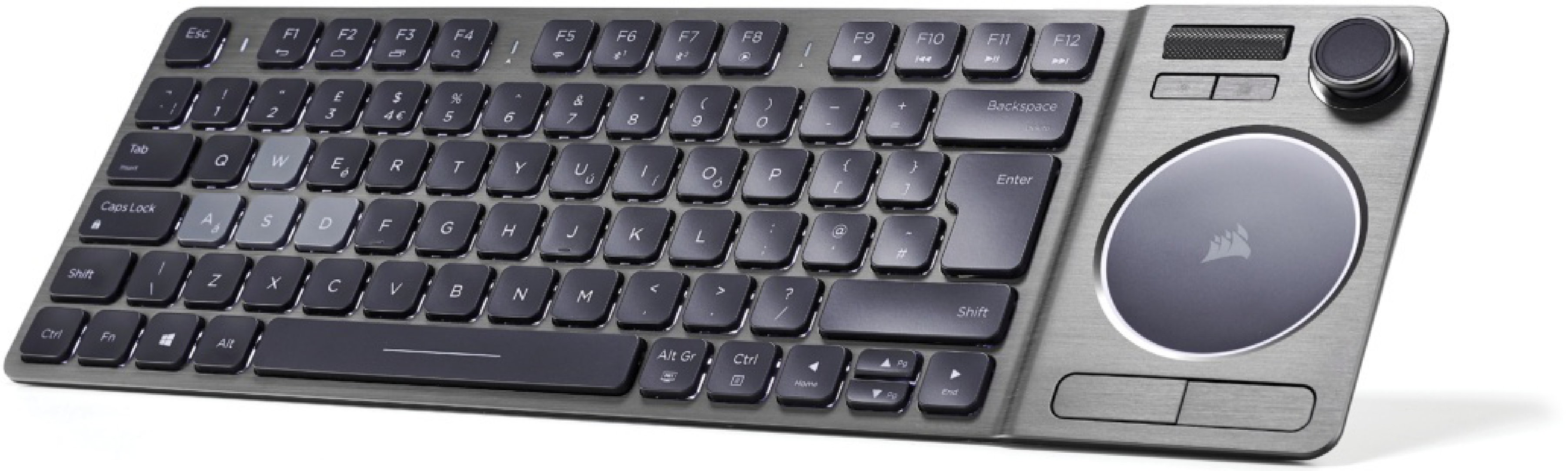
+ FOURSOME Sturdy shock mount; crystal clear; looks the part for streamers.

− QUAD DAMAGE It's not an XLR studio mic.

$140, www.hyperxgaming.com

SPECIFICATIONS

Frequency Response	20Hz–20kHz
Sample/Bitrate	48kHz/16-bit
Cable Length	3 metres
Polar Patterns	Stereo, omnidirectional, cardioid, bidirectional
Element	Electret condenser
Power Consumption	5V 125mA



Corsair K83 Wireless Entertainment Keyboard

Lean back, relax, and poke your desktop from afar

SOME WOULD HAVE YOU THINK that the appropriate place to use a PC is not hunched in front of a monitor at a battered desk scarred with the corpses of keyboards past. Increasingly, that notion is true: Nvidia's BFG displays, to name one example, are bringing acceptable response times and minimal lag to our living rooms, meaning no-compromise pixel-pushing is putting its feet up on the couch and getting comfy. It follows that our control methods should evolve along with the games and media we're moving out of the office, right? Hence this.

Let's make one thing clear, though: Corsair's mini board is by no means alone in the space. Others are out there cooking up their own solutions for couch control, and Roccat's Sova—a big plank of a keyboard, with adequate flat space on its right edge to run a real mouse on a real surface—arguably has the better idea when it comes to games. Corsair points this at "entertainment" control, and despite its clearly delineated WASD cluster, that's probably the fairest way to rate it. To do that, we need to inspect the real meat, and that's all on the right edge.

You can't miss the big circular touchpad, which, although supporting four-finger gestures, feels specifically designed for one-thumbed pointing. Gesture support obviously adds a little media control flexibility, which is important, because Corsair has put its media keys on double duty with the F9–F12 keys. In action, that touchpad is the perfect size when holding the right edge, even if you have thumbs like a ballpark hotdog, but flip your hand palm down, and it's just too small and awkward to use consistently with a finger.

The touchpad is not the only quirky control method included, as Corsair has also dropped in a configurable analog joystick above it. Sticks are hard to get right at the best of times, and we can't exactly say this has succeeded. Contrasting the too-small touchpad, the stick is just too large, and it covers a vast distance when moved. With it comes a pair of buttons, one on the shoulder, one much larger and sitting on the underside, within one of the K83's two grip channels. Certainly clever placement, as they're both easy to reach, but the execution is middling at best—their glossy finish means the base button in particular is indefinite and easy to miss or mispress.

THE RIGHT STUFF

We're following a common thread here. In theory, we're blown away by the K83's design. It hits the mark on its weight, on its materials, on its strength, and its battery. Its subtle white lighting and blend-in mix of grays and blacks means it works well in a dim room, but doesn't make a scene when you're not actively using it. It's versatile, offering a pair of Bluetooth connections as well as its own (much more responsive) wireless receiver. But there are so many things that don't quite work so well, and when you add in the click-to-mute feature of the volume control—too stiff compared to the looseness of the knurled roller, meaning you're taking a gamble every time as to whether you'll mute it or turn it way up—they're basically all on the right edge. That's supposed to be what makes this special.

Even with its niggles, the K83 is not a disaster. It's a great little low-profile keyboard, with brilliantly tactile keycaps, and enough travel and distance between keys to make it more pleasant than the typical laptop experience. It looks great, and we could see ourselves using it long-term with a media PC. But not a gaming PC. Even if the mouse cluster had fulfilled its potential, it wouldn't have reinvented the wheel. **–ALEX COX**

VERDICT
6

Corsair K83 Wireless Entertainment Keyboard

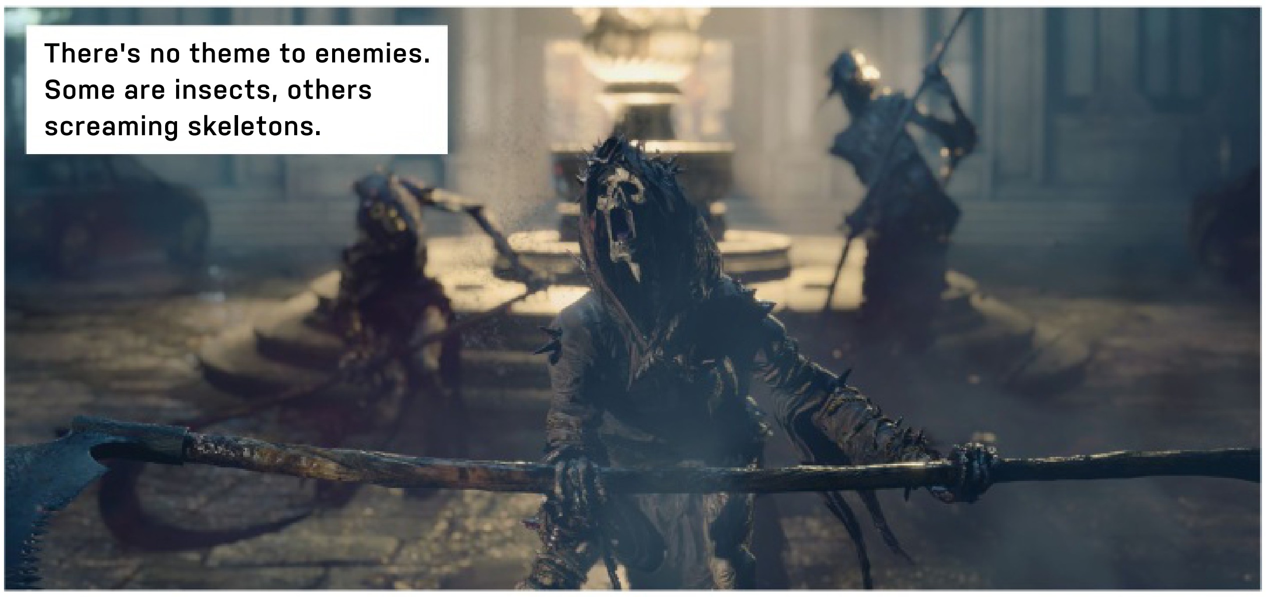
⊞ **CIRCLE** Comfortable typing feel; good looks; tough construction.

⊟ **SQUARE** Odd joystick; awkward joystick buttons; too-small touchpad.

$100, www.corsair.com

SPECIFICATIONS

Switch Type	Corsair Gaming Scissor
Form Factor	Tenkeyless
Media Keys	Yes
Macro Keys	Software configurable
LEDs	White
N-Key Rollover	20-key
Pass-Through	No
Dimensions	15 x 5 x 1.1 inches
Weight	1.1lb
Warranty	Two years



There's no theme to enemies. Some are insects, others screaming skeletons.

Bosses tower over characters and buildings.

Nico not only drives the van, but creates arms for Nero too.

The city is London-like, with red call boxes.

Devil May Cry 5

Who you gonna call?

FOLLOWING THE RELEASE of the *Resident Evil 2* remake, Capcom is on a roll, and is bringing its console games to PC in exactly the right way. The engine is a monster, and console ports that once would arrive with little or no customization options are now taking full advantage of PC graphics.

Devil May Cry is a console-centric series of third-person brawlers, however, that has not always appealed to the PC faithful. It calls out for a controller, although mouse and keyboard controls have been given the same amount of thought as the rest of the game. It also deserves to be played at the highest frame rate you can manage—dropping down to 1080p is a small price to pay for smooth demon-killing.

DMC games are a strange mix of the deep and the shallow, the smart and the dumb. The plot follows an insectoid demonic invasion, which can only be stopped by young men who also have a touch of the Luciferian about themselves and can string fighting moves together like you've never seen. There are three protagonists: Dante, Nero, and V, each of whom have different fighting styles. Dante uses swords and guns, and also in one memorable scene a motorbike that comes apart into two ax-like weapons, with multiple fighting styles. Nero can switch between mechanical arms that destroy demons in different ways. And V can summon a demon, big cat, and griffon to do the fighting for him.

It's all very silly, preposterous even, the tone set by a slow-motion intro sequence that has its tongue firmly in its cheek. The game's depth comes from the fighting combos, as you prowl around its levels killing just about everything that moves, and collecting orbs that lead to upgrades. A system of ratings, applied at the end of each level, supplies the impetus to replay to improve your skills, but the sight of characters sliding smoothly between lock-ons, gunshots, weapon sweeps, moves that pull you into the faces of enemies, then explosions that knock you back out of harm's way is reward in itself. There's even a weaponized hat you can throw on to enemies' heads, even those of bosses.

It's also taken the New Game + concept, which, once you've beaten the campaign once, deposits you at the beginning of the game with all your unlocked gear and skills to face harder and refreshed enemies. So much is changed, it feels like a continuation rather than a restart.

DMC5 is flashy dumb fun that's going to repel as many as it attracts, but it's great to see the series on PC with a port that's had so much thought and love put into it. If you've never played a game in the series before, this is a great place to join the hype train. **–IAN EVENDEN**

VERDICT

8

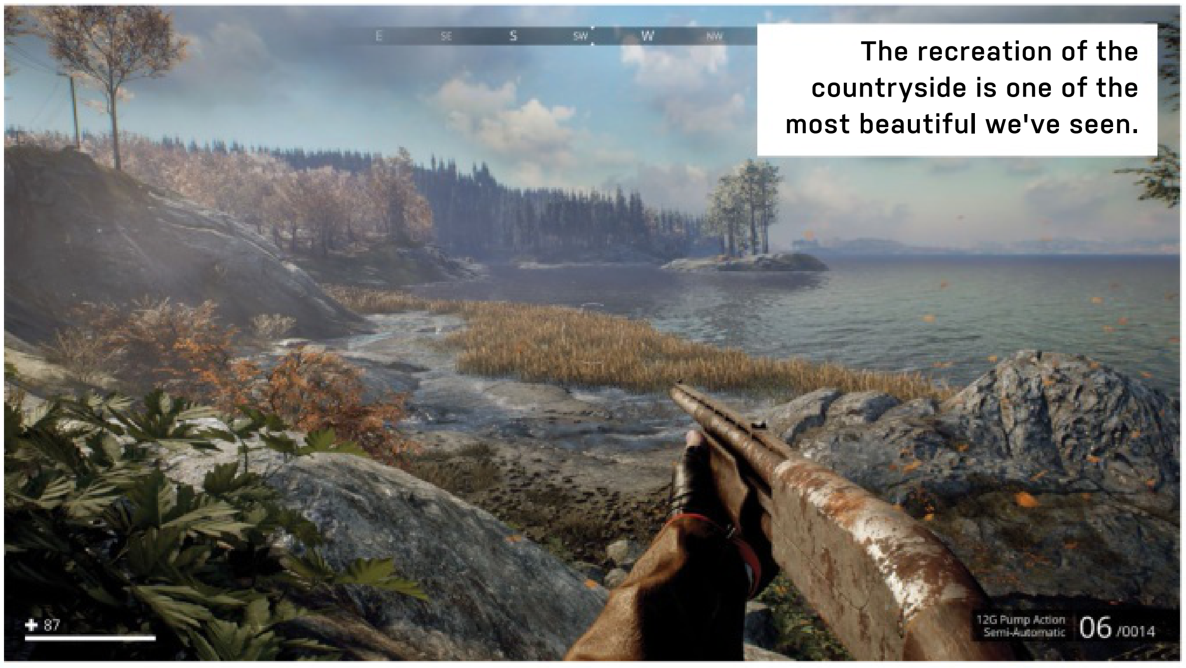
Devil May Cry 5

+ **REVELS** Fast; good looking; easy to pick up; tricky combat.

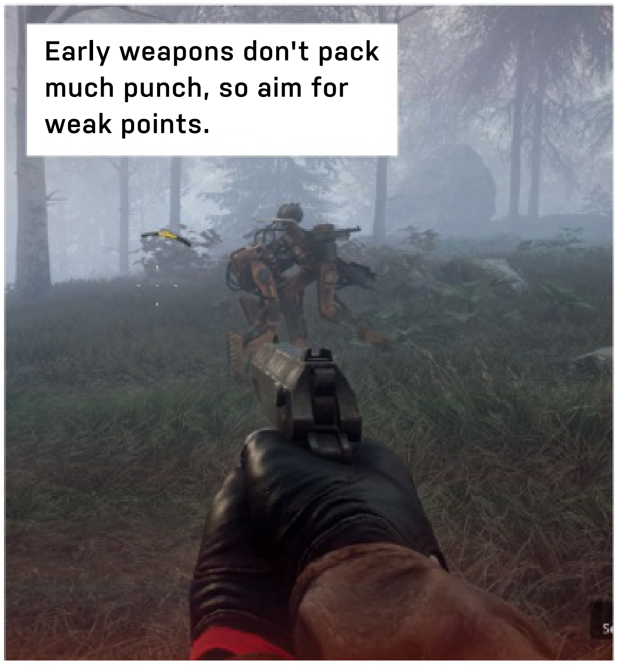
− **DEVILS** You might wonder what's going on.

RECOMMENDED SPECS i7-3770/FX-9590; 8GB RAM; GTX 1060 6GB/RX 480 8GB.

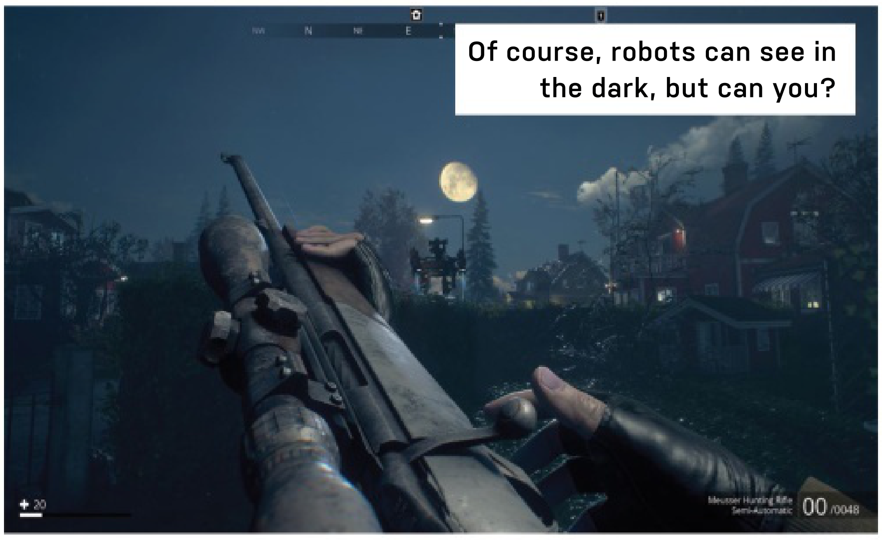
$60, www.devilmaycry5.com, ESRB: M



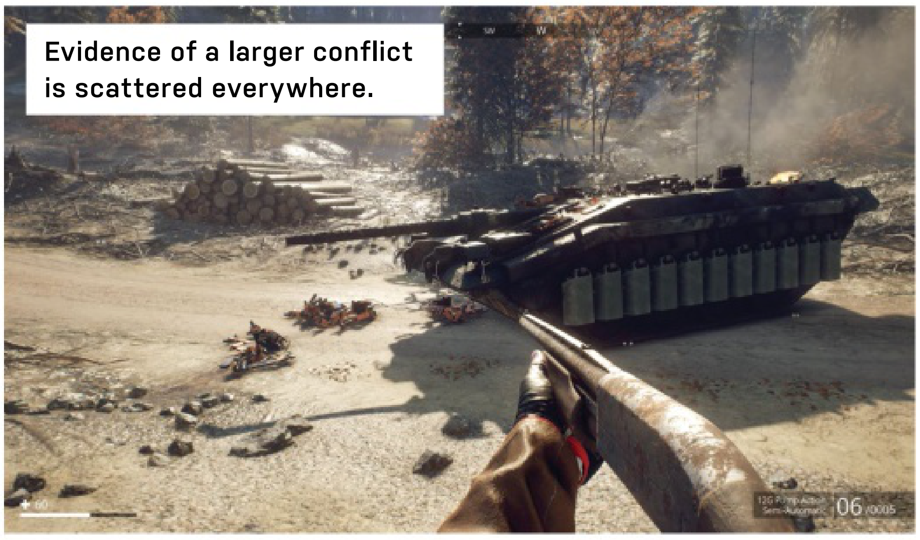
The recreation of the countryside is one of the most beautiful we've seen.



Early weapons don't pack much punch, so aim for weak points.



Of course, robots can see in the dark, but can you?



Evidence of a larger conflict is scattered everywhere.

Generation Zero

There are stranger things than you in Sweden

FILLING THE SWEDISH countryside with robots and 1980s references looked like such a good idea from a distance. Avalanche's game blends *Fallout 76* with *Everybody's Gone to the Rapture* and *Stranger Things,* with nods to the art of Simon Stålenhag (look him up, thank us later), and the end result is one of the most beautiful recreations of a natural landscape we've seen in videogames.

A co-op shooter for up to four that can be played solo, *Generation Zero* suffers most from its emptiness. It's a slow starter, the lack of human NPCs beyond a few corpses contributing to a fantastically eerie atmosphere, but it's also repetitive. The houses and outbuildings you search for the backpacks that contain anything from clothing to ammo to fireworks are depressingly similar, the same meals on the table, the same boxes and bicycles in the garage.

And while it may feel like a survival game, it isn't. There's no need to pick up food and water. The first aid kits you weirdly appear to eat significantly boost your health bar, and any clothing you pick up is hived off into a separate section, rather than going in your main inventory. Which is a bonus, because the inventory is awful—a grid-based system without easy access to items in the heat of battle, and if you have a stack of items assigned to a quick-access key, any more of those items you pick up don't stack with it.

Frustratingly, there is so much good game design here, fighting to get out. While the enemy robots are initially thin on the ground, the way they escalate is intelligently paced, the distance you trek into the map defining what you're likely to face. There's a visual feedback system to tell you if your shots are doing damage, and the indicator that you've been spotted gives you loads of warning, allowing for a stealth approach to combat in most instances. Sound is integrated well, and radios become as useful for distracting bots as fireworks are for stunning them.

One early battle took us by surprise, with more robots than we'd faced up to that point, especially as we'd just picked our way through an empty village where a burning tank suggested we'd find something to shoot at. Robot models are few, making it easy to identify each by its silhouette, and the time period means they have fuel tanks, rather than tiny batteries, making one-shot kills a real possibility. Flying bots make an analog modem noise when calling in reinforcements, helping you track them down for dispatch.

The dev behind *Just Cause* and 2015's *Mad Max* can do better than this. It's a beautiful world and enticing premise, but it's too slow, with too many frustrations, to fully recommend. **–IAN EVENDEN**

VERDICT
6

Generation Zero

+ CYBERNETIC Beautiful world, beautiful idea; fun with friends.

− ANAESTHETIC Too-pervasive feeling of cold emptiness; quickly becomes repetitive.

RECOMMENDED SPECS i7 quad-core or equivalent; 16GB RAM; GTX 960/R9 280.

$35, www.generationzero.com, ESRB: T

LAB NOTES

JARRED WALTON, SENIOR EDITOR

Epic Games Store Plays the Game

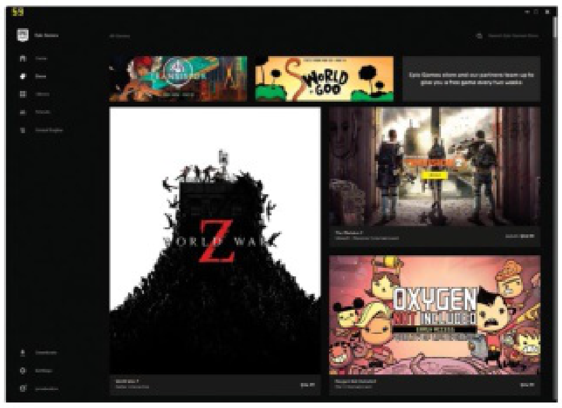
Steam's rival gives its users a free game every two weeks

ONE OF THE BIGGEST controversies of 2019 so far has been the Epic Games Store—and more specifically, EGS paying for timed exclusives. Formerly the home of *Fortnite* and *Unreal Tournament,* EGS is now looking to take on Steam. And after procuring *Metro Exodus* in February, EGS has added several more high-profile games to its list of timed exclusives: *Borderlands 3, The Outer Worlds, Control,* and *Vampire the Masquerade—Bloodlines 2.* Needless to say, there are more than a few unhappy gamers.

I understand why people are upset. Steam is convenient, it works well, we have Steam friends lists, it supports cloud saves, you can easily transfer files between PCs, and more. But I also fully support Epic's choice to compete, especially when it's doing so not only with timed exclusives, but also by giving away free games every two weeks, reinvesting $200 million into game developers, "no strings attached," and perhaps most importantly by taking 12 percent commission compared to Steam's 30 percent. (Steam has added a tiered commission structure, where it reduces its cut to 25 or 20 percent for games that reach $10 million and $50 million in sales, respectively.)

Steam is good but it's certainly not perfect, and EGS is a lot like Steam was back when it first launched. But just like Valve used *Half-Life 2* as a means of boosting Steam into the stratosphere, Epic is now attempting the same thing via *Fortnite.* Plus, I'm already used to having half a dozen game launchers, and as far as privacy goes, I'm far more concerned with my smartphone than with anything that Epic might learn from my gaming habits.

Epic has a lot to work on, and it has a roadmap for EGS updates already laid out. Is Steam's dominance finally starting to falter? We won't know for certain for at least a couple of years.



A little competition is no bad thing.

JOANNA NELIUS

Staff Writer

I've been thinking about the preservation of PC games. Maybe the discless Xbox One has something to do with it, but that's old news as far as PC gaming is concerned; desktop PCs don't come with an internal CD drive these days, as games are available digitally. It's something to have screenshots or video of a DOS game, but it's another to still be able to play it. That's why I'm happy sites such as ClassicReload.com and places like the Museum of Art and Digital Entertainment exist. As physical media continues to lose relevance, it's important that we don't forget our own history when it comes to PC games and the once cutting-edge hardware needed to run them.

BO MOORE

Hardware Lead

Well, this is embarrassing. I've been using a SteelSeries Arctis Pro headset for the last year or so, and one of its hallmark features is a game/chat mixer that lets you balance the levels between in-game sounds and voice chat using a handy physical dial. Problem was, I could only get the game channel to work, while the voice channel always sounded garbled. So, I just ran everything through the one side and never fiddled with the dial. A small annoyance, but whatever. Well, it turns out it was a problem with one of my USB ports. I switched to a different port last week, and now the mixer works perfectly. I'm psyched. I just wish I'd figured this out a year ago.

Editors' Picks:
Digital Discoveries

Staff writer, Christian Guyton, and executive editor, Alan Dexter, discuss what's been entertaining them recently

WARFRAME

What have I been doing this month? Getting sucked back down the rabbit hole that is *Warframe*. This free indie title about heavily armed space ninjas recently hit its sixth anniversary, and I've been playing on and off since release, but when the game's open-world Plains of Eidolon update launched in 2017, the user numbers were catapulted into the stratosphere, and it hit 50 million registered users following the release of the huge Fortuna update. Props to the fantastic dev team, Digital Extremes, who hosts regular events and livestreams to keep in touch with its community.

Why do I keep coming back to it? *Warframe* just has the magic a game needs. Yes, it's grindy as hell, often crushingly difficult, and the learning curve is more like a learning cliff. But there's a moment when it clicks—you take control of the complex movement system, and fly through the air to slash an enemy soldier in two, before spinning around and unleashing a hail of bullets and magical projectiles. It does a flawless job of making you feel powerful but rarely overpowered. Do I recommend it? Sure. Just don't be afraid to ask for help in the chat.

Free, www.warframe.com

ATOMIC HEART TECH DEMO

I've been rocking an Asus ROG Strix RTX 2080 Ti since the start of the year, and I've really enjoyed not having to worry about the settings for pretty much any game I throw at it. Even though I'm connected to a 4K screen, everything just works, and looks awesome. There are always exceptions, of course, and bizarrely the only time I have to dial things back is with ray-tracing titles—I simply can't set everything as high as they will go and expect smooth frame rates in *Metro Exodus, Shadow of the Tomb Raider,* or *Battlefield V.* Which is slightly galling given that each one only demonstrates one aspect of the ray-tracing arsenal—global illumination, shadows, and reflections.

The tech demo for *Atomic Heart* dropped into this environment, and reignited my interest in ray tracing. Not only does it show off the full range of effects in its spin around a fictional laboratory-cum-museum, but it also hints at a game that may genuinely benefit from such effects. It is just a tech demo, of course—the final game may be some way off, and it may not live up to its full potential—but I can't help but hope that real-time ray tracing has more to offer than we've seen so far.

Free, https://mundfish.com

EVGA GeForce RTX NVLink Bridge

PAIRING UP GRAPHICS cards in SLI is a high-end endeavor these days, which is a shame for anyone who remembers the joy of slamming two GeForce 6600 GTs together for a cheap yet incredibly powerful solution. Still, if you want to hit the higher echelons of polygon processing, it's hard to argue against doubling up. The promise of increasing performance almost twofold is too much to resist for some.

To get the most out of such a setup, you need an NVLink bridge, which hardwires the two cards together. You can get a basic bridge direct from Nvidia, but if you want something a little more exciting, this EVGA NVLink Bridge may be right up your alley. It throws RGB into the mix as well, which could be exactly what you need to show off your expensive graphics setup. Available in three-slot and four-slot models, these colorful bridges look good in a variety of builds.

There is a small problem, though, and it isn't something we can lay at EVGA's door: Modern SLI performance is patchy at best. Grab a selection of the latest games, and there's a good chance that less than half of them will show any improvement. Indeed, in some cases, performance can be much worse than with a single card. It depends on the game in question, of course, with some behaving better than others, and if you want the very best, you need one of these bridges, but it isn't an option for anyone looking for good value for money. **–AD**

$90, www.evga.com

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON…

> Puzzling Packaging
> Audio Clarity
> Keyboard Issues

Dodecahedron Fun

It's been too long and I'm upgrading. I bought an Intel Core i9-9900 CPU, and it arrived in the all-time strangest box I've ever seen. I confess that it took me a minute to figure out how to open it (look for the tape holding it together). If I'd been given a choice of saving $10 and getting a regular box, I would've gone that route. The rest will be easy. **–Steve G**

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: While Intel is the latest to produce some frankly ridiculous packaging, you can't lay all the blame at its door, as AMD's Threadripper chips set the level that Intel felt it had to beat. It's fairly obvious that this has been done to make the whole experience more of an event for the end user, which is particularly relevant when you're dropping so much money on something.

To be honest, we quite like the packaging of this (and AMD's Threadrippers) just because they are a bit out of the ordinary. But at the same time, you're right—we're paying for this packaging, and once you've got the important thing out of it (you know, the actual chip), what are you supposed to do with what's left? Display it on a shelf, before throwing it in the bin? That probably.

9TH GEN
CORE i9
UNLOCKED

The i9-9900K's packaging isn't to everyone's tastes.

Sound Check

Phil Iwaniuk's article on soundcards ("The Sound of Silence," May 2019 issue) contains a statement that gaming audio "is compressed to accommodate smaller download sizes, so tends to max out at CD quality, 44,100Hz sample rate and 16-bit linear depth." CD quality is not compressed. The specs he quotes are the red-book audio standard for CDs, which carry uncompressed audio.

What am I missing? Is there a red-book standard for compressed audio I don't know about? Or does "compressed" mean something different in gaming? Please tell me this isn't just another example of a computer magazine making a hash out of the art and science of audio reproduction.

He also says HD audio is "largely a marketing conceit to sell headsets with higher specs." I assume he's referring exclusively to its use in games. The golden-eared critics at *Stereophile*, *Absolute Sound*, and other high-end audio magazines would disagree. They say anyone can hear the improvement that, say, 96kHz 24-bit sound makes over "CD quality" audio. **–Thomas V. Lento**

CONTRIBUTING WRITER, PHIL IWANIUK, RESPONDS: It's an issue of semantics—CD quality is the absolute best you get in games that don't offer HD audio, but there's a gamut: Many games do compress their audio files below that of CD-quality standard. And, yes, I'm talking about gaming hardware marketing—but I'd contest that anyone can hear the difference. We all have different hearing levels. If you've spent the last 20 years playing drums in a thrash metal band, you're perhaps not going to notice that high-end sparkle as much as a teenager with fresh, undamaged ears.

Smaller and Smaller

Can you make your print any smaller? Why don't you just sell blank pages? I would learn just as much from them. **–Tom Lamb**

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: We actually increased the font size throughout the magazine a few months ago, but if you and other readers are still finding it hard to read, get in touch, and we could increase the size again.

New for Old Gear

Here's a head-scratcher for you. I don't have as much time for gaming as I used to, and my game box was a Z97/Core i7 platform that's obviously five years old at this point. I had no particular problems with

↘ submit your questions to: comments@maximumpc.com it, and my 1080p gaming experience was fine—until while working on the machine, I shorted out and burned up the CPU fan header. No big deal, I'll just pick up another used board and get on with life—but I looked and discovered that gaming-class used Z97 boards (and their higher-end matching CPUs) are the same price as buying a new board. Not wanting to throw good money at a five-year-old platform, I built a new Ryzen box that should hopefully serve well for several years.

I realize we're in the post-Moore cloud-based future already, but I can't figure out why five-year-old used parts command prices equivalent to brand new gear. **–Mike Pepe**

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: We see artificially high prices on old hardware quite often, but the problem seems to be particularly bad when it comes to gaming hardware. It's a seller's market, and if you're looking to pick up an older machine on the cheap, including the words "games," "game," or "gaming" can double the asking price. When it comes to a Z97 motherboard, you're a bit more limited, and savvy sellers know who will be buying. Ultimately, though, we think you've probably done the right thing, and ended up with a machine that should serve you well for the next five years.

Classic Start

Michael Wiplich wrote in the March issue that he was having problems installing Windows 7 on a new machine—that does not support it. His wife hates Win 10 (as does mine). I found a neat free program that can be customized to suit. Get rid of that horrible Win 10 desktop, and his wife might like it. Classic Shell, 6.9MB, made by Ivosoft. We have it on two desktops and one laptop, and like it a lot. **–Bill Cook**

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: We've looked at Classic Shell a number of times in *Maximum PC,* in numerous features and tutorials, and we've always been impressed by its simplicity and intuitive design. It's no longer actively developed, but the source code has been released on GitHub, and there's still a reasonable amount of discussion about how to access various features using the tool. If anyone is interested in grabbing the latest version, you can download it from www.classicshell.net.

Out of Key

After reading the *Maximum PC* "Kick Ass 9" review of the Wooting keyboard, I decided to buy one. I don't like to be negative, and I do whatever I can to make something work, but this was one of the worst purchases I've made in quite some time: The 1 key stutttttttters, and the 8 and = keys don't work at all. (If I mash them down and hold them for a few seconds, sometimes something will happen, but usually not.)

There are other personal preference things that I don't like, but those are subjective. The objective things (um, the keys just plain don't work) are unacceptable for that kind of money. I tried moving switches around, but the same thing kept happening at the same locations. I tried varying the actuation level; no change. I updated the Wootility; no change.

The knowledge base: basically useless. Discord: That's a joke. Contacting Wooting: "We're very busy right now." I really liked the idea of supporting a startup with a good idea. I just wasn't ready for having to do their QC and R&D for them for the money I paid.

I don't expect you to do anything, I just wanted to let you know that not everyone has had the same wonderful experience as *Maximum PC* has with this keyboard. **–Ken Furman**

We contacted Wooting's CEO and founder, Calder Limmen, and he responded promptly: "What the reader is experiencing is difficult to determine at first, since there are many elements that can influence the result. Especially since it's beyond a simple metal contact switch.

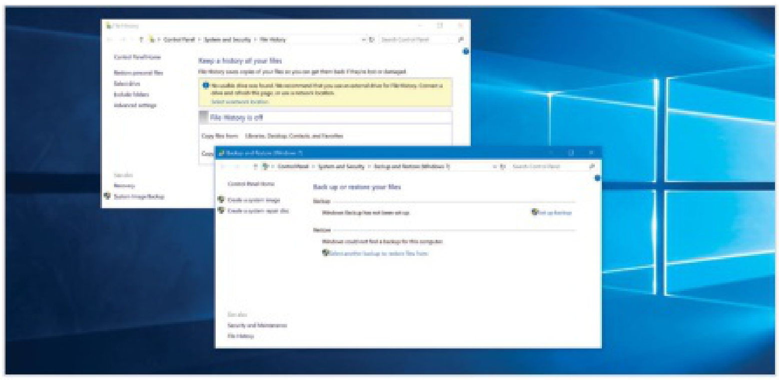
"If a key isn't responding at all, it shouldn't even get through QC, so we always suspect software/firmware first, which is usually fixed with a simple restore. As we never stop development in that department, USB is complicated, and Windows doesn't always play nice, bugs/glitches are always a fact with new releases. That's why you're always notified to update the firmware at first use. If it's hardware, it's a serious concern on our side, and I wish it never happened, but that's impossible.

"In the reader's case, it seems at first that the switches are at fault—hence the recommendation to swap them for others. But if a key isn't responding at all, and software-wise everything is in check, this would be marked as a hardware defect, and we can send over a new board.

"In general, (simple) software-related issues and getting settled with the keyboard are solved on Discord. Otherwise, we welcome anybody to contact our support at social@wooting.io. On average, we respond within three working days, and come with solutions not excuses."

[NOW ONLINE]

HOW TO BACK UP WINDOWS 10



Whether you just want to back up your files or create an entire copy of Windows, we've got you covered. As our lives become increasingly integrated with digital technologies, keeping your most treasured memories and files backed up in one fashion or another is one of the most important things you can do. But keeping your Windows 10 installation backed up is a great idea, too, because if something major goes wrong, you can revert to it, and get back to work or play more quickly than a full reinstall.

Just as there are many third-party backup utilities that offer all sorts of different features, though, there are also different ways that you can back up Windows 10. You might opt to protect the bare minimum, or create a complete clone of your system to return it to exactly as it was, should something go awry.

Read the full article: https://bit.ly/2UZbqJW

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THE BUILDS

BUDGET

INGREDIENTS

PART		PRICE
Case	BitFenix Nova TG	$55
PSU	450W Corsair VS450 80+ White	$40
Mobo	ASRock B450M R4.0 AM4	$65
CPU	AMD Ryzen 5 2600	$165
GPU	Gigabyte GeForce GTX 1660 6GB	$220
RAM	8GB (2x 4GB) Team T-Force Vulcan @ 3,000MT/s **NEW**	$50
SSD	120GB Crucial BX500 2.5-inch SSD **NEW**	$22
HDD	1TB Seagate Constellation ES 3.5-inch HDD	$38
OS	Ubuntu Desktop Linux 18.04 LTS 64-bit	$15

Approximate Price: $670

THERE WASN'T TOO MUCH WORK to be done on the budget build this month. There was a slight rise to the cost of Seagate's hard drive, but there was nothing we saw fit to do about that—the fact is that Seagate drives are the still best value around for beefy HDD storage, so we took the hit. Elsewhere, though, we were able to trim the fat a little—swapping out our ADATA Ultimate SSD for a Crucial BX500 of the same size saved us a few dollars, and we traded out the RAM, too, getting rid of the American Patriot Viper memory for the 8GB kit from Taiwanese manufacturer Team Group's T-Force Vulcan line, with only very minor trade-off in performance. This made for a small saving, enough to offset the five-dollar price rise on the ASRock B450M motherboard. Most other components held steady this time around, resulting in an overall price change of just three dollars less.

MID-RANGE

INGREDIENTS

PART		PRICE
Case	Fractal Design Meshify C	$90
PSU	550W Corsair CX550M 80+ Bronze	$60
Mobo	Asus ROG Strix B450-F Gaming	$130
CPU	AMD Ryzen 7 2700	$240
Cooler	Cooler Master MasterLiquid Lite 240mm RGB AIO **NEW**	$70
GPU	Zotac Gaming GeForce RTX 2060 6GB	$350
RAM	16GB (2x 8GB) Team T-Force Vulcan @ 3,000MT/s **NEW**	$85
SSD	250GB Samsung 970 Evo Plus M.2 PCIe SSD	$88
HDD	1TB Seagate Constellation ES 3.5-inch HDD	$38
OS	Windows 10 Home 64-bit OEM	$100

Approximate Price: $1,251

A SUDDEN, UNWELCOME HIKE in the prices of Corsair's all-in-one coolers had us re-evaluating our mid-range build this month, eventually opting for a far more affordable (if slightly less flashy) option: Cooler Master's MasterLiquid Lite—try saying that five times fast. Cooler Master lives up to its name; similar in scale to the Hydro H100i Pro we had been using, the MasterLiquid Lite comes packed with RGB lighting and produces minimal noise. Oh, and it's 40 dollars cheaper than Corsair's offering. Sold! Elsewhere, we swapped out the RAM, too—again choosing the T-Force Vulcan series, using a 16GB kit this time. Team T-Force might not be the highest-end memory brand, but it does the job. We gleefully saw that prices were dropping all over the place for this build; the Ryzen CPU dropped by 10 dollars, and the mobo by five. Overall, this build comes out at a winning $57 cheaper than last month.

TURBO

UPGRADE OF THE MONTH

512GB GIGABYTE AORUS RGB M.2 NVMe SSD

RGB on your SSD? Sure, why not? Honestly, we love this little drive for other reasons: It's speedy enough to compete with Samsung's dominating M.2 SSDs, with a sleek integrated heatsink. This is the first SSD to come with motherboard-compatible RGB lighting, so if you're rocking a modern Aorus mobo, you can link them together for bonus bling. Otherwise, Gigabyte's RGB Fusion 2.0 software is freely available. The 512GB model offers up to 3,480/2,000MB/s read/write speeds, and comes with a five-year warranty, making the $120 price tag all the more attractive—already a surprisingly affordable price for a fast, flashy M.2 drive like this. **$120, www.gigabyte.com**

DETECTING A THEME? It feels like RAM upgrade month here. We've gone for a pretty straight upgrade to the Pro version of Corsair's Vengeance RGB memory, a set of two 16GB sticks that deliver solid performance at a better price per gigabyte. Threadripper CPUs have leapt up in price—the 2950X is a relatively inexpensive one, but still dropped an extra $40 on the price of this build this month. A quick switch of the GPU saved us 10 dollars, moving away from Asus and over to MSI's bulkier RTX 2080, which rocks an extra DisplayPort and two fans, as opposed to one, albeit with an ever-so-slightly lower boost clock. The biggest saving, though, was made on the SSD. Samsung's 970 Pro is a lightning-fast drive, but it comes with a price tag that leaves us feeling like we've been lightning-struck; we saved nearly 50 dollars by moving to the 512GB Gigabyte Aorus RGB M.2 SSD, released earlier this year. RGB on an M.2 drive might seem a little over the top, but this SSD is a nifty piece of gear with a sensible price. The RGB tech gave Gigabyte room to include a heatsink on the top of the SSD, meaning there's no need to shell out for motherboards that come with removable M.2 heat shields. No fiddling around with sticky pads, either. Seagate's BarraCuda HDDs mercifully didn't rise in price, so our 2TB of reserve storage remained safe. Overall, this build came out $43 cheaper than last month—and probably about 10 percent more colorful.

For more of our component recommendations,
visit www.maximumpc.com/best-of-the-best

INGREDIENTS

PART			PRICE
Case	NZXT H700i		$180
PSU	750W Corsair RM750X 80+ Gold		$110
Mobo	ASRock X399 Phantom Gaming 6		$240
CPU	AMD Threadripper 2950X		$840
Cooler	Be Quiet! Dark Rock Pro TR4		$90
GPU	MSI GeForce RTX 2080	NEW	$700
RAM	32GB (2x 16GB) Corsair Vengeance RGB Pro @ 3,000MT/s	NEW	$225
SSD	512GB Gigabyte Aorus RGB M.2 NVMe	NEW	$120
HDD	2x 2TB Seagate BarraCuda ST2000DM006		$120
OS	Windows 10 Home 64-bit OEM		$100

Approximate Price: $2,725

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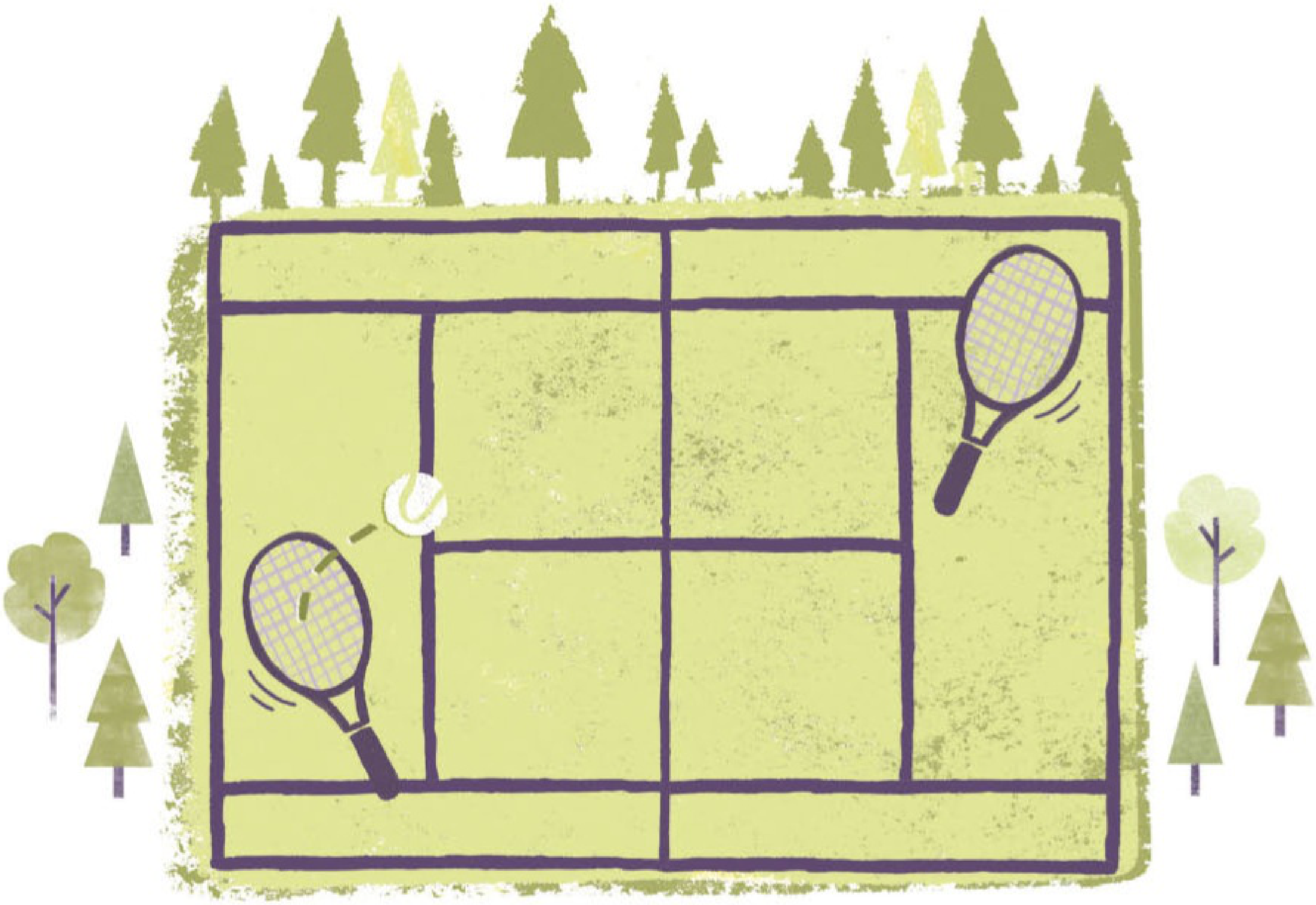

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UNFAO, Global Forest Resources Assessment 2005-2015

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